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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXIII.—No. 2935.] *LONDON: FRIDAY, MARCH 31, 1922.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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See Advertisement, pages 27 and 67, last week.
PATENT WATER-TUBE BOILERS, AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

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See Illustrated Advertisement Page 100, Jan. 28, 1921.

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Steam and Electric Cranes,
EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS,
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PORTSMOUTH.
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ENGINEERS & BOILER MAKERS.

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 17, March 24. 9947

The Mitchell Conveyor and
TRANSPORTER CO., LTD.,
CONTRACTING ENGINEERS.
DESIGNERS and BUILDERS
of
all Classes of HANDLING MACHINERY.
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Telephone: Holborn 286. 9759

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London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
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Diesel Engines, Six Cylinder, two and four stroke, 350, 1000, 1200 H.P. Excellent condition. Dynamos for above 250 or 500 Volts, D.C. Immediate delivery and low price.
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All classes of mechanical and structural work undertaken. Special plants designed and supervised during erection. Contracts for plant and machinery handled and supervised throughout.
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Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 9746
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HEAD OFFICE: 84, Robertson Street, Glasgow.
See Advertisement page 75.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, } ROW'S PATENTS.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

Tubes and Fittings,
IRON AND STEEL.
Stewarts and Lloyd's Ltd.,
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MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—132, BUTE ST.
BIRMINGHAM WAREHOUSE—NILE STREET, SHEEPSCOTE STREET.
See Advertisement, page 26. 9963

Economy!
HIGH BOILER EFFICIENCIES
ARE OBTAINED BY INSTALLING
Todd Oil Burners
FUEL OIL BURNING SYSTEMS,
HEATERS, STRAINERS.
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TODD SHIPYARDS CORPORATION,
Builders of Steam and Motor Ships, Repairers, Electric Drive Installations.
Twenty-one Floating Docks, Two Graving Docks, Twelve Shipways.
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Patent
See's Hydro-Pneumatic Ash Ejector.
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4535

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John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice-Making Machinery.
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&c. &c. 9404

A Time Recorder, as New, guaranteed, latest model. WHAT OFFERS?—A. G. PELLEY, 149, Farringdon Road, E.C. 1. F 509

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Lifts.
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THE GLASGOW ROLLING STOCK AND PLANT WORKS.
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Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON and BRASS CASTINGS, PRESSED STEEL WORK OF ALL KINDS.
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Water-Tube Boilers.
9564
Messrs. YARROW & CO. UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

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STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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Head, Wrightson & Co.,
LIMITED.
See Advertisement page 61, March 24. 9469

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"OILDAG" (Reg.) BRAND. **"AQUADAG"** (Reg.) BRAND.
GRAPHITED GREASE.
"GREDAG"
9605
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Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 609

GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED.
Duckham's Patent Suspended
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c. See Illus. Advt. last week, page 15. 9764

WAYGOOD-OTIS LIFTS. 9488
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62 & 63, LIONEL STREET, BIRMINGHAM.
and Principal Provincial Cities.

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Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
9731
See half-page Advertisement page 72, March 17.

See Advt. Page 84 March 24.
Steam Hammers
Power Hammers
Steam AND Friction
Drop Stamps.
B. & S. Massey, Ltd., 9611 MANCHESTER.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 596

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THE "ARCHIBALD DAWNAY" SCHOLARSHIP.

This SCHOLARSHIP of £50 a year tenable for three years by a student who intends to enter some branch of the Engineering profession, will be OFFERED for COMPETITION at the College Entrance Scholarship Examination which begins on April 22, 1922. Further particulars and a form of application can be obtained from the undersigned, to whom the form of application must be returned on or before April 15, 1922.

D. J. A. BROWN, Registrar.

Cardiff, March 29, 1922. T 867

Correspondence Courses for B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to Mr. TREVOR W. PHILLIPS, B.Sc. (Hons.), Assoc.M.Inst.C.E., M.R.S.I., etc., 8-10, Trafford Chambers, 58, South John Street, Liverpool. 575

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., M.I.E., A.M.Inst.C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Thousands of successes during the last sixteen years. Courses may commence at any time.—39, Victoria St., Westminster, S.W. Tel. 4780 Victoria. 566

Inst. C.E. Exams.—Successes as usual last Exam. by Correspondence Coaching. Successes by hundreds, several prizes. Sec. "C" embraces 25 years' professional experience. Address, 7454, Offices of ENGINEERING.

Penningtons, University TUTORS, 264, Oxford Road, Manchester. Estab. 1876. Postal courses for all Engineering Exams. Enrol now for I.C.E. and I.M.E. Courses. 100 per cent. passes last Exams. 9750

TENDERS.

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply

of :—
1. RODS, Point, for Signal Apparatus.
2. ENGINES, Locomotive.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E.1, and Tenders are to be delivered at that Office not later than Two o'clock p.m. on Friday the 21st April, 1922, for No. 1, and on Tuesday, the 2nd May, 1922, for No. 2.

T. RYAN, Director-General. T 868

TO CONTRACTORS ONLY.

THE COMMISSIONERS OF HIS MAJESTY'S WORKS, etc., are prepared to receive

Tenders before Eleven

a.m., on Thursday, 4th May, 1922, for the SUPPLY OF ENGINEERING LABOUR during the period of Three Years in the following districts :—
LEEDS (MECHANICAL).
NEWCASTLE (ELECTRICAL AND MECHANICAL).
SOUTHAMPTON (ELECTRICAL AND MECHANICAL).

Forms of Tender, etc., may be obtained on application to the CONTRACTS BRANCH, H.M. OFFICE OF WORKS, King Charles Street, London, S.W.1. T 869

COUNTY BOROUGH OF BIRKENHEAD WATER COMMITTEE.

FOR SALE.

The Corporation are prepared to receive

Offers for the following PUMPING PLANT, which is FOR DISPOSAL, owing to the coming into operation of a new Gravitation Supply, and is all in excellent working condition.

A Compound Rotative Beam Engine, surface condensing with bucket and plunger pumps, capacity 80,000 gallons per hour with a total lift of 265 feet at a boiler pressure of 90 lb. per square inch HP., Cylinder 30 in. dia. by 3 ft. 10 in. stroke, L.P. Cylinder 50 in. dia. by 7 ft. stroke, Bucket 7 ft. stroke.

Two Triple Expansion Horizontal Duplex Pumps, steam cylinders 10 in. to 16 in. and 26 in. dia., water cylinder 14 in. dia. by 18 in. stroke, capacity (each) 45,000 gallons per hour against a head of 300 feet at a boiler pressure of 150 lb. per square inch.

Two Surface Condensers, Wheeler Admiralty Pattern, 3 ft. 4 in. dia. by 6 ft. 10 in. between tube plates, 452 ¾ in. copper tubes (each), with steam driven horizontal Air Pumps complete.

Two Lancashire Boilers, 30 ft. by 7 ft. by Tetlow Bros., insured for 150 lb. W.P.

One Lancashire Boiler by The Oldham Boiler Works Co., Ltd., insured for 100 lb. W.P.

Two Lancashire Boilers by The Oldham Boiler Works Co., Ltd., insured for 100 lb. W.P.

All the Boilers above mentioned are fitted complete with Hopkinson Valves and mountings.

Any further information and also permits to view the Plant may be obtained from the BOROUGH WATER ENGINEER, 93, Balls Road, Birkenhead, to whom Offers for the whole or portions of the Plant should be sent not later than April 14th, 1922.

Water Engineer's Office, 15th March, 1922. T 791

BENGAL-NAGPUR RAILWAY COMPANY LIMITED.

The Directors are prepared to receive

Tenders for all or any of the

following :—
OPEN AND COVERED GOODS WAGONS AND BRAKE VAN UNDERFRAMES, 2 ft. 6 in. gauge.

Specifications and forms of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad Street, London, E.C. 2, on or after 27th March, 1922.

A fee of £1 1s. will be charged for the specification, which will not be returned.

Tenders must be submitted not later than Noon on Monday, 10th April, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order of the Board, R. C. VOLKERS, For Managing Director. T 836

COUNTY BOROUGH OF CROYDON.

SELHURST PUMPING STATION.

GAS ENGINE AND PUMPS.

NOTICE IS HEREBY GIVEN that the Council are prepared to receive

Tenders for the Supply and

ERECTION of a GAS ENGINE and PRODUCER PLANT, with DEEP WELL PUMPS and SURFACE PUMPS for Pumping water from Well into Service Mains of the Town.

Specification, Conditions and Form of Tender may be obtained on application at the Borough Engineer's Office, Town Hall, Croydon, upon payment of a deposit of One Guinea which will be returned upon receipt of a *bona fide* Tender.

Tenders on the prescribed form to be sent to me by Eleven o'clock in the forenoon of SATURDAY, 22nd APRIL, 1922, endorsed "Tender for Gas Engine and Pumps, Selhurst Pumping Station."

Tenders will only be received subject to the draft Contract, Specification and Conditions deposited at my Office, and which may be inspected during Office hours.

The Council will not be bound to accept the lowest or any Tender.

JOHN M. NEWNHAM, Town Clerk.

Town Hall, Croydon. 28th March, 1922. T 857

METROPOLITAN WATER BOARD.

TENDERS FOR OVERHAULING, REPAIR and RENEWALS to a COMPOUND WORTHINGTON PUMPING ENGINE at Hammersmith Pumping Station.

The Metropolitan Water Board invite

Tenders for Overhauling,

REPAIR and RENEWALS to a COMPOUND WORTHINGTON PUMPING ENGINE at their Hammersmith Pumping Station.

Forms of Tender, Conditions of Contract, Specification, and Drawing may be inspected without payment of fee at the Offices of the Board, Chief Engineer's Department, Room 182, New River Head, 173, Rosebery Avenue, Clerkenwell, E.C. 1, on and after Monday, April 3, 1922.

Contractors desirous of tendering may obtain the necessary documents from Mr. HENRY B. STILGOE, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £1 1s. 0d., which sum may be deposited with the Board's Accountant, and will be returned on receipt of a *bona fide* Tender, together with all incidental papers. Such payments and applications must be made between the hours of Ten a.m. and 4.30 p.m., Thursdays excepted (Saturdays Ten a.m. and Twelve noon).

Tenders enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, 173, Rosebery Avenue, E.C. 1," and endorsed "Tender for Overhauling, Repair, and Renewals to a Compound Worthington Pumping Engine, Hammersmith," must be delivered at the Offices of the Board not later than Ten a.m. on Wednesday, April 19th, 1922.

W. MOON, Clerk of the Board.

Offices of the Board, 173, Rosebery Avenue, E.C. 1. 27th March, 1922. T 850

STEPNEY BOROUGH COUNCIL.

ELECTRICITY SUPPLY.

(A) CONVERTING PLANTS.
(B) OVERHEAD CRANE.

The Electricity Supply Committee of the Stepney Borough Council invite

Tenders from Responsible

Contractors for the CARRYING OUT of the following WORK :—
(a) The Manufacture, Supply and Erection complete of Three 1,000 Kw. CONVERTING PLANTS suitable for converting H.H.T. 6000 volts, 3-phase A.C. current to L.T.D.C.
(b) The Manufacture, Supply and Erection of one 50-ton Electrically-driven Overhead GANTRY CRANE, with gantry girders and rails; also the dismantling and alteration of an existing hand-driven crane and the re-erection of the same at one of the Council's sub-stations.

Copies of the General Conditions, Specifications, Forms of Tender and Drawings may be obtained from Mr. W. C. P. TAPPER, M.I.E.E., Borough Electrical Engineer and Manager, No. 37, Osborn Street, Whitechapel, E.1., upon receipt of a deposit of Two Guineas for each specification (a) and (b). Deposits will be returned to *bona fide* tenderers after the Tenders have been considered by the Council. Additional copies may be obtained upon payment of the sum of 10s. 6d. per copy, which will not be returned. Copies of the specifications and drawings may be inspected at the above-mentioned address by appointment.

Tenders, on the form supplied, endorsed "Tender for Converting Plant" and "Tender for Crane" as the case may be, must be delivered, signed, sealed and addressed to the Chairman of the Electricity Supply Committee, at No. 37, Osborn Street, Whitechapel, E.1., not later than Noon on April 20th, 1922.

The Council do not bind themselves to accept the lowest or any Tender.

GEO. W. CLARKE, Town Clerk.

Municipal Offices, Raine Street, Wapping, E.1. T 860

The Midland Railway COMPANY have FOR DISPOSAL at Derby, A LARGE QUANTITY OF OAK, produced from the breaking up of old wagons, as follows :—

Headstocks... About 7 ft. 6 in. by 11 in. by 4½ in.
Solebars ...About 14 ft. 5 in. by 11 in. by 4½ in.
Curb Rails ... About 14 ft. 11 in. by 4½ in. by 4 in.
Rails, etc. ... ... Various Sizes.

Offers are invited, and intending buyers should quote a price "per ton" to the STORES SUPERINTENDENT, at Derby, to whom all enquiries respecting the material should be addressed.

Purchasers will be required to pay all carriage charges. T 876

STOCK OF ENGINEERS' SMALL TOOLS FOR SALE.

Offers are Invited for Stock

of SMALL TOOLS—Drills, Reamers, Taps, Dies, etc., belonging to McPhail, Bond & Co., Ltd. (In Voluntary Liquidation), 69, Robertson Street, Glasgow. The Stock is in first-class condition, and the present cost price per inventory and valuation prepared by Messrs. J. & R. Edmiston, Licensed Valuators, Glasgow, is £1884 11s. 8d. Copy Inventory can be had from the Subscribers, with whom offers should be lodged.

JOHN PRACOCK, C.A., Liquidator.

111, Union Street, Glasgow. T 834

THE BURMA RAILWAYS COMPANY, LIMITED.

The Board of Directors of the Burma Railways Company, Limited, are prepared to receive

Tenders for the Supply of :—

12 tons 4½ cwt. PAINTS.

For each copy of the Specification a fee of 10s. will be charged, which fee is not returnable. Tenders, enclosed in sealed envelopes, and endorsed "Tender for Paints," must be delivered at the Company's Offices not later than Twelve Noon on Monday, 10th April, 1922. The Directors do not bind themselves to accept any or the lowest Tender, and reserve the right to divide the order.

By Order of the Board, F. C. FRANKS, Secretary.

199, Gresham House, Old Broad Street, London, E.C. 2. 30th March, 1922. T 877

CORPORATION OF DUBLIN.

The Streets Committee of the Corporation of Dublin is prepared to receive

Tenders for the Supply and

DELIVERY in Dublin of ONE 12 in. by 8 in. PORTABLE STONE CRUSHER and SCREEN.

Copy of Specification and Conditions of Contract can be obtained on application to the undersigned between the hours of Ten and Four, Saturdays excepted.

Tenders, endorsed "Tender for Stone Crusher," should be addressed to the Chairman, Streets Committee, Municipal Buildings, Cork Hill, Dublin, and should be delivered not later than Twelve noon on Tuesday, 11th April, 1922.

The Committee does not bind itself to accept the lowest or any Tender.

By Order, JOHN J. MURPHY, Town Clerk, Secretary Streets Committee. Municipal Buildings, Dublin. 29th March, 1922. T 878

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely :—

No.		Fee for Specification.
1.	Points and Crossings,	£1 0 0
2.	Galvanised W.I. Water Tubes, etc.	10s.
3.	Brass and Iron or Steel Screws,	10s.
4.	Fencing Materials,	10s.
5.	Bellows,	2s. 6d.
6.	White Lead,	£1 0 0
7.	Galvanised Corrugated Sheets, Etc.	7s. 6d.
8.	Spring Steel,	£1 0 0
9.	Pig Iron,	£1 0 0
10.	Plate Glass, etc.	10s.
11.	Fencing Wire Strand,	7s. 6d.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Points and Crossings," or as the case may be, not later than Eleven o'clock a.m. on Tuesday, the 11th April, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE, Secretary.

Company's Offices, 48, Copthall Avenue, London, E.C. 2. 29th March, 1922. T 874

APPOINTMENTS OPEN.

THE UNIVERSITY OF LIVERPOOL.

MUNITIONS COMMITTEE FELLOWSHIPS IN ENGINEERING.

Applications are Invited for

these FELLOWSHIPS (two in number) from persons qualified to undertake research in any department of Engineering. The fellowships are tenable in the first place for one year (value £350 each), and may be renewed for a second year (£350 each). Form of application and full particulars may be obtained from the Registrar, The University of Liverpool, to whom application should be forwarded before 1st June, 1922.

EDWARD CARNY, Registrar. T 840

Wanted. — Good Leading

MECHANICAL DRAUGHTSMAN for Power Station Construction.—Address, stating age, present employment, experience, and salary required, T 880, Offices of ENGINEERING.

STAFFORDSHIRE EDUCATION COMMITTEE. COUNTY TECHNICAL COLLEGE, WEDNESBURY.

An Assistant Lecturer in

Engineering is REQUIRED. Salary will be paid according to the Burnham (Technical School) Scale.

Candidates must be qualified to give class-room and laboratory instruction in Mechanical Engineering and related subjects. Works experience is desirable.

Further particulars and forms of application, which must be returned not later than 20th April, may be obtained from the undersigned on receipt of a stamped addressed envelope.

GRAHAM BALFOUR, County Education Offices, Director of Education. Stafford, March, 1922. T 732

Technical Assistant Required

in the Estimating Office of engineering firm in London handling heavy steam, electrical and air-compressing machinery. Thorough technical training and a fair experience with steam plant calculations and lay-outs essential. A working knowledge of French or German an advantage.—Address, giving particulars of training and experience and stating age and salary in last position, T 850, Offices of ENGINEERING.

Editorial Assistant Wanted

by an Engineering Institution, to carry out the following duties under the direction of the Secretary :—Reporting meetings ; preparing matter for the Proceedings which are issued fortnightly ; and generally assisting in the editorial work. Candidates should state their age, educational qualifications, journalistic experience, salary required. The appointment need not necessarily be a whole time one.—Applications to be sent to T 854, Offices of ENGINEERING.

Engineer Required for Large

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Salary £490, rising annually by £30 with house or house allowance, and duty allowance of £56. Five years' agreement, with first-class free passage out and home on completion of agreement. Appointment subject to medical examination.

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India Office, 17th March, 1922. T 846

MASS PRODUCTION IN GEAR-CUTTING.

By JOSEPH HORNER.

Two movements associated with the practice of gear cutting are predominant at the present time. One is the insistent demand for gears of the highest degree of accuracy, superior to those which have been produced hitherto with the standard sets of rotary disc cutters, the other is the imperative need for mass production of hundreds or thousands of small gears identical in all respects, accurate, fulfilling the condition of interchangeability on mechanisms, at prices that are not prohibitive. Gears too, that though of fine pitches, are subject to severe wear, and are therefore cut in materials tougher and stronger than the old cast-iron and mild steels, and which are frequently either case-hardened or uniformly heat-treated. Mass production enables the two conditions of a high degree of accuracy and of prices not prohibitive to be realised.

The subject also embraces an enlarged sphere which includes forms that were not employed extensively when only the older gear-cutting methods were in vogue. The improved systems have brought into prominence and much favour the worm gears, the spiral gears, the helical and double helical forms, while bevels, formerly produced with rotary cutters giving unsatisfactory results, are now planed with forms or by generation, and the latter method is also applied to produce the teeth of the helical or spiral form of bevel wheel. With the growth of these methods, the dimensions of the cut gears have been greatly increased, and massive machines have been built to deal with gears that were and are still mostly cast in machine-made moulds. These demands for accurate gears, required in large numbers, are having their result in the abandonment of old methods, the scrapping of old machines, and the evolving of new or modified systems, and new machines generally specialised.

The mass production of gears is reflected in the difference between the old and the later shops. Formerly an unimportant appanage of the general machine shop, the gear-cutting department is now located in a separate area or building. Rows of machines, many being identical, are grouped in line, and different types are represented, each suited best to some particular kinds of gears. Machines that generate are indispensable, and satellite appliances are adjacent. The manufacture of the machines is the work of a limited number of firms whose names are familiar, and a catholic selection from these is apparent in many shops.

Our subject wears two aspects. One is that which concerns the different classes of gears cut, with the diverse methods adopted for obtaining the desired results, the other is that of the methods generally associated with the mass production of all kinds of gears. The latter embraces such matters as the division of operations between roughing and finishing, and the mounting of several blanks in series when that is practicable, and the use of multiple cutters. When these are not available, the economies afforded by some types of machines over others have to be balanced.

The older practice of employing rotary disc form cutters, which is being abandoned for high-class gears, is retained for the roughing out of teeth, to be finished by generating systems. This division of operations between roughing and finishing has always been adopted when dealing with the coarser pitches. It is done when the teeth are finished with disc cutters, special gashing cutters being provided for the purpose, having teeth coarsely pitched and notched. This is done in order to conserve the edges of the finishing cutters, by retaining them for fine cutting only. It also favours more accurate results. Another reason is the avoidance of local heating. If coarsely pitched teeth are finished singly out of the solid, local heating will be set up with some resulting distortion, which is avoided if the teeth are first gashed round nearly to size. Then, too, the finishing cutter being subject to light duty, preserves its keenness of edge, and the last tooth will be shaped like the first, and the cutter not having become dulled will not be thrust away radially, with local increase in the radius of the teeth. With bevel gears, in all but the finest pitches, a central roughing parallel cut is taken before the formative cuts are employed. And so with most gears of coarse pitch, worm wheels, helicals and double helicals—gashing cuts are taken, and sometimes the blanks are laid aside to season to allow of the relief of internal strains. While these methods are appropriated from the older practice, they are now vastly extended to embrace blanks dealt with *en masse* to meet the requirements of motor vehicles, of all descriptions of machine tools, and in a lesser degree of all specialised articles of manufacture that must interchange.

The first attempts at mass production are those which are associated with the work done on the spur gear-cutting machines, using rotary disc cutters. The design with a vertical work arbor, and having the cutting tool mounted on a vertical slide lends itself well to increased production. A pile of gear blanks can be mounted on the arbor, and supported with a tooth rest against the pressure of the cutter. If the upper end of the arbor is supported with a bracket, the slogging capacity is greatly increased. The same broad design is adopted in many of the spur gear hobbing machines—the vertical work arbor with bracket support. These will take a single deep gear, or several of shallow face. Similarly, spiral gears can be cut in piles on the spur gear machines that are made to angle the cutters, or on the more specialised spiral gear-cutting machines, some of which use hobs, some the rack cutters. A high degree of accuracy is secured when either of these is substituted for the rotary disc cutters. And there is no risk with either of the setting up of local heating, with distortion. In the case of the hob, the blank makes many revolutions while the hob is being fed down the face. Using a rack cutter, the teeth on which it is operating are undergoing roughing and finishing, the lower teeth of the cutter roughing, the upper finishing. In each case, the teeth in the gear, when of coarse pitch, can be stocked out with a rotary disc cutter on one of the older designs of machine.

Mass production takes account of a due balancing of theoretical and practical degrees of accuracy. It has to consider wisely the choice of methods that are most suitable for the accomplishment of the ends desired. With every refinement in measurement and gauging the cost is enhanced, as it is also by the substitution of alloy steels for the carbon steels, and for cast-iron. And for all common mechanisms these materials and the employment of rotary disc form cutters for the teeth are suitable, and the cost is much less than for the others. It is because any one class of gear can be produced by dissimilar methods that the question and the difficulty of choice arises. Thus spurs, spirals and double helicals can be shaped either with disc cutters, with rack cutters, pinion cutters, or hobs. The selection of either method gives rise to different views on the part of the management. Associated with this are the capacities of different groups of machines which vary widely, both in the case of those which are installed in a shop, and those that are marketed. In the last resort firms are often compelled to have machines designed for their own precise requirements, to be occupied with work that is being repeated through many consecutive months.

A single rack tooth is used to generate involute gears. But a length of rack containing five or six teeth, backed off, hardened and ground will perform the work more expeditiously, since it will be in simultaneous action with several teeth in a wheel of large radius. The cutter is fed tangentially to the wheel blank in the intervals of the reciprocations of the cutter across the face of the blank. The relative feeding movements of the cutter and blank are those which occur in the actual rack and its wheel. One cutter will generate all wheels of the same pitch and pressure angle. No modifications in the cutter profiles are required even with a low-pressure angle, if the addenda of the small pinion are lengthened and those of their wheels shortened. Since the cutter has but five or six teeth, and it has to be brought into contact with the entire periphery of the blank, it is necessary, after a distance of one pitch has been cut, to index the cutter backwards by a distance equal to one tooth or pitch. No single tooth is finished during one indexing, but portions of several, within range of the cutter, are being shaped, some being roughed, portions of others being finished. The edges of the cutters are preserved, and time is economised by gashing the spaces in the coarser pitched gears with a cutter that bottoms. The rack cutter is used for spiral gears, and for single and double helicals, the cutter being selected for the normal pitch, or that at right angles with the direction of the helix. The spur gear cutting machine may be employed with the necessary provision for angling, but it is better to allot the work to distinct machines.

The value of the pinion cutter as a means of generation is testified by the growth of the practice. Originating with the Fellows' it is now adopted in the David Brown, and the Sykes' machines, with certain improvements. It will cut spurs, spirals and helicals, but for the latter, the straight spindle for the cutter is replaced by one having a helical guide of the required lead. This is preferable to the employment of change gears, being positive and rigid.

A feature of the David Brown machine is that the cutter and blank are rotated at their correct relative speeds according to their pitch diameters, so that the pitch lines of both have the same circumferential velocity. This being continuous, dispenses with the need for a separate indexing mechanism. The ram with its cutter is reciprocated vertically, cutting on the down stroke, during the simultaneous rotation. The mechanism is so designed that, putting on equal dividing change gears, when the work-table makes one revolution, the cutter spindle makes two, so accommodating a blank the pitch diameter of which is twice that of its cutter. For any other ratio the change gears are obtained thus:

$$\frac{\text{Driving gears}}{\text{Driven gears}} = \frac{\text{Number of teeth in cutter} \times 2.}{\text{Number of teeth required in blank.}}$$

The cutter is relieved during the return stroke. The stroke of the ram is adjustable to suit the depth of face of the gears being cut.

Beyond the fact that the pinion cutter is employed in the Sykes' machine it has no resemblance to the others named. The axes of the cutters are disposed horizontally, and two are used, doubling the output, while the arrangement permits of the production of large gears. They are reciprocated and rotated simultaneously in unison with the rotary motion of the blanks. The permanent gears are arranged so that it is only necessary to put on a driver change wheel equal to the number of teeth in the cutter, and a driven change wheel equal to the number of teeth to be cut. The cutters are relieved on the return strokes. All these provisions economise time, while the method employed is that of generation. The two cutters—duplicates—shape all teeth of the same pitch and pressure angle. And no corrections are required for low numbered pinions if the addendum lengths are increased, as previously mentioned.

The hobbing process, the last method named, is a valuable asset in mass production. In addition to the greater output by comparison with that obtained by the employment of rotary disc cutters, it generates correctly-shaped teeth, and is adaptable for all external teeth of parallel sections—spurs, spirals, double helicals, and for worm wheels with unsymmetrical teeth, for which hobs were originally employed. The theory on which the hobbing method is based is, that the section of its thread is that of the basic rack tooth in the involute system. The value of this principle is enhanced by the corrective action of the helical thread as its teeth come into successive action—a feature of high utility which is not possessed by the single disc cutters, no matter how closely their sections may approximate to the theoretical forms. With these, each tooth space is worked singly without reference to those adjacent, so that inaccuracies that are liable to occur in the pitching are not subject to any corrective interference. The hob is self-corrective, and, in addition, by reason of its gradual depthing of face and shaping of the teeth in successive revolutions of the blank, internal stresses and strains are released, which the disc cutters do not equalise unless a preliminary gashing is done all round. A hob also has many more cutting edges than a disc cutter, since each revolution of

the helix is cut into teeth by the spiral grooves that traverse the hob at right angles with the direction of the helix. As a set-off to the greater expense of a hob by comparison with disc cutters, one hob suffices for all gears of the same pitch, since it is essentially the basic rack. Its action is that of a rack traversed at the same rate as the pitch line of the blank being cut, the rack teeth removing metal and generating the tooth forms.

The question arises, as in other cutters, of the most useful tooth proportions to be given to hobs. The old pressure angle of 15 deg., and the B. and S. tooth lengths are frequently abandoned in favour of higher angles of 18, 20, or 22 deg., and stub teeth. A standard must be selected, and if another should be required the hob must be made to the new standard. Hobs are cut with a slight angle of thread—about 3 deg., and the axis is tilted to the angle of the thread, while the profile of the rack tooth lies in this tilted axis. Some hobs are corrected in order to avoid a very slight thickening of the points of the teeth cut, the hob flanks being thickened, and the sides slightly concave. It is necessary to set the hob with one tooth centrally with the centre line of the blank. If this is not done, the teeth cut will be slightly out of upright, and the depthing will not be correct. As the cutting action of the hob is not continuous, due to the intermittent action of the teeth, a series of minute flats is left on the work, but these are soon obliterated with wear. But if the number of teeth on the hob is lessened the flats are reduced. So that the larger the numbers of the teeth, and the larger the diameter of the hob, the finer will be the finish. But speed must be lessened, and the difficulties of manufacture increase.

A large output is secured with a hob in any case by comparison with that of a single disc cutter. But to get the best results possible, machines must be stiffly built, with shafts large and rigid to resist the torsional stresses of cutting. If they spring, the output will be reduced, and the teeth will not be so close to accuracy. Later machines show to great advantage here. It is generally specified that a machine will cut to a certain diametral pitch in iron and in steel. Production is doubled in one of the Gould & Eberhardt machines by the inclusion of two work spindles, set as usual in the vertical position. Each spindle has independent horizontal adjustment, so that the correct thickness of tooth can be cut, even though the diameters of the hobs may vary. Immense economies are effected in the cutting of sprocket teeth with hobs, in place of disc cutters. Having narrow faces, piles of a dozen, more or less, can be mounted on a vertical arbor to be cut with a hob mounted on a vertical slide. The upper end of the arbor is steadied with a bracket.

The cutting of double helical teeth has developed in the direction, not only of a higher grade of accuracy, but in several machines, of lessening the time by one half. Originally, the teeth on each side were produced separately, as they are still in most machines, rotary disc cutters being employed, the same as those for spiral gears of similar pitch and lead. But latterly machines have been introduced which cut both sets of teeth simultaneously in machines using, some hobs, others pinion-like cutters, each dealing with an extensive range of sizes. But there is an essential difference between the two groups. If the teeth must be continuous at the apex, only the planing process, using a rack cutter, or a pinion cutter can be employed for generation. These will plane to a line. The alternative is an end mill, which leaves a radius at the apex, but this is not a generating method, and the mill, being small is liable to more rapid wear than even the disc form cutter. If a hob is employed, or a rotary disc cutter, the teeth must either be discontinuous, with a clearance space between, or, if brought to the centre, they must be staggered.

Double helical gears are generated with two hobs, working simultaneously on opposite sides of the wheel in the Falk machine. The teeth are of the Wust type, hit and miss, the teeth on one half entering the spaces of those on the other half. There is no central clear space, but the teeth are discontinuous. The blank is carried on a central table that rotates. The hobs are supported on housings that flank it, and which are adjustable for radii along the bed of the machine. The cutter heads are fed vertically on the housings. One hob commences cutting at the top edge of the blank, the other, at the side opposite, at the bottom edge. The angle of the teeth is obtained by synchronising the feed of the hobs with the rotation of the work table. Roughing hobs stock out the tooth spaces, leaving only a little for finishing. Adjustments of the housings, and of the cutter heads is effected with lead screws, the errors of which are guaranteed not to exceed 0·001 in. per foot of length.

This machine affords a striking illustration of the increasing demands that are now made for accurately generated gears of the largest dimensions, combined with a good output. These would generally be moulded by machine, in which case the teeth are continuous. The Falk hobber will admit wheels up to 16 ft. 3 in. diam., and 6 ft. face. A 30 h.p. motor drives the arbors, and the table. Another of 7½ h.p. traverses the housings along the bed. Cutter heads are counterweighted. The machine weighs 150 tons.

The Fawcus machine employs two hobs mounted on one housing, producing teeth disposed symmetrically, but discontinuous at the apex. The hobs are carried on a head sliding vertically on a housing, the blank being centred on a vertical arbor, the table carrying which is adjustable horizontally along the bed, thus following the common design of hobbing machine. The special features of the design are those which concern the rotation and feeding of the two hobs. The blank is turned with a groove at the centre, where the apex of the teeth would lie if continuous, the width of groove being made about equal to the circular pitch. When cutting, one hob starts work at the top of the blank, cutting down to the groove, the other begins at the groove, working down to the bottom. The upper hob rotates in a clockwise direction, the lower one counterclockwise. As both hobs are acting in unison, errors in spacing which may arise when the two halves of the teeth are cut independently are eliminated. The machine is somewhat complicated, since it includes provision for driving the hobs, for imparting the differential motions to the hobs, for rotating the work, for horizontal setting and feeding of the work, and for the vertical power feed for traversing the hobs across the face of the wheel blank. All are derived from a single belt pulley, or from a gear, which is motor driven.

The mutual support which is afforded to the teeth in the continuous helical design explains why that is preferable to that in which the teeth do not meet at the apex. But those, if generated must be produced either with a rack, or a pinion cutter.

The rack cutter double helical generating machine by Messrs. David Brown and Sons, employs the Sunderland rack with half a dozen teeth. Two operate, one for each spiral. They reciprocate across the face of the blank, cutting to the apex at the centre of the width. The slide which carries the two cutters travels vertically upwards, while the blank is rotated at the correct speed. When the slide has moved through its predetermined distance, and the cutters are in the non-operative position, clear of the blank, the movements are arrested. The saddle is then indexed through a distance equal to one, or more pitches, after which the reciprocating motion of the cutters, and the rotary movement of the blank are re-started simultaneously. Relieving mechanism is fitted, with clapper boxes pivoted on the reciprocating cutter slides, so that the cutters clear the blank on their return strokes. After the cutter saddle has completed its upward movement for cutting it is tripped for a quick return stroke. The axis of the work lies horizontally in a headstock integral with the bed. Provision is made for holding blanks solid with their shafts. The capacity of the machine includes gears up to 36 in. diam., by 6 in face, and up to 1 in. circular pitch, or 3 d.p.

The Sykes' machine operates two pinion cutters simultaneously, the axis of the work being disposed horizontally. The reciprocating, and the rotary motion of the cutters and the rotation of the blanks are connected. The cutters are relieved during the return stroke. The change wheels are so designed that calculations are not necessary. The permanent gears are arranged so that it is only necessary to put on a driver change gear, having the same number of teeth as the cutter, and a driven change wheel equal to the number of teeth to be cut. The setting-up is so simple that one man is able to attend to three machines. They cut spur gears also. They are of great utility in the manufacture of turbine reduction gears. The range of capacity of the entire series of machines built is very large. They will cut from ½ in. to 5 in. pitch, diameters up to 12 ft., spirals up to 30 deg. Cutters can be made to any pressure angle. And using the standard 15 deg. angle, the smaller pinions can be made without undercut by lengthening the addenda. This is an example of large production, combined with a large range of dimensions, and of generated teeth of a high degree of accuracy. The tooth angles are imparted positively through helical guides, the right and left hand pinion cutters can be used for single helical gears, and if desired, staggered teeth can be cut on double helicals.

The production of internal teeth with rotary form cutters is open to the same objections to their use for spur gears. Yet no other method was available before the introduction of the pinion cutters, now used for this work on the vertical spindle type of machine. And in machines fitted with a helical guide, internal helical teeth can be cut. Sprockets and ratchets are also produced with pinion-like cutters, having teeth of suitable shapes. Cluster gears in close proximity are cut, since the movement of the cutter can be arrested to a line.

(To be continued.)

DEEP WATER QUAYS.

By ERNEST LATHAM, M.Inst.C.E.

THERE has always been some attraction to engineers in constructing deep water berths in partially-protected tidal waters, as against the more costly equivalent accommodation provided by dock construction. There is no question that for the discharge and loading of certain cargoes, dock accommodation is essential with the relative levels of ship and quayside unaffected by the rise and fall of tide. The heavy cost of deep concrete or masonry quay walls, locks, gates and other accessories, however, brings up the cost per lineal foot of quayside greatly beyond that for which, under favourable conditions, deep water tidal jetties or quays can be constructed. The author's actual experience has been principally confined to the Thames Estuary, where his firm have been either responsible for construction, or had to report on many structures of this type. The River Thames and its estuary offer at points suitable sites for this class of berthage, and from Erith down river there has been for a number of years steady industrial growth along the river-side, especially amongst trades seeking deep-water accommodation and for whose special class of traffic tidal berths are suitable.

By the end of the Great War ships up to 20,000 tons deadweight were berthing in this manner in the Thames Estuary. The trades for which this relatively cheap class of quayside accommodation appears to be suitable are coal, oil, paper and cement, or, in short, those trades which load or discharge principally in bulk, barrels, kegs or sacks, and do not necessarily require transit shed accommodation within a few feet of the berthage. The policy of the Port of London Authority, while naturally tending to the protection and maintenance of dock traffic, has of recent years been liberal towards private enterprise down river, thereby giving industrial undertakings every encouragement to construct their own quayside works, and the author has never met with anything but encouragement and assistance from the technical officers of the port.

The cost and speed of construction vary largely with the design employed, and the materials selected for the works. Generally, there is both need for economy and rapidity of construction since, for some obscure reason, those responsible for establishing riverside factories or warehouses postpone decisions as to their marine works till the last moment, not

clearly foreseeing that this section of their enterprise is for reasons obvious to the maritime engineer, the slowest section of the constructional work.

The principal types of jetties and wharves in the Thames are sharply divided into two classes, each permitting of many variations in design, viz. :—

(*a*) Reinforced concrete.
(*b*) Timber.

With reinforced concrete, as with every departure from older practice, it is hard to determine to whom should be given the actual credit for the innovation. Reinforced concrete was originally developed as a novel form of construction by French engineers, and had reached a great vogue also in this country, prior to the Great War, numerous specialist "Licensing Companies" having sprung into being. The author, amongst others, was at first very favourably inclined towards this method of construction, as applied to this particular branch of engineering, but experience has now taught him where part of the structure. The actual magnitude of the lateral forces exerted on a jetty by impact from ships making the berth or colliding with it is, of course, indeterminate, but it is obviously less the greater the safe "give" or "spring" of the structure. Reinforced concrete piles, cylinders or structures do not adapt themselves to movements of this character without disintegration. Further, in the case of actual collision, where extensive damage is often caused in the case of reinforced concrete structures, it is difficult to trace the extreme limits of damage or to say how far the strength of the structure has really been impaired. That these are not prejudiced objections is proved by the illustrations here reproduced.

The photograph Fig. 1 shows the result of a collision between one of the liners of the Messageries Maritimes and a deep-water jetty built in reinforced concrete. The vessel in this case was about 6,000 tons register; there were 30 ft. of water at low tide at the jetty in question, and the ship was off water berthage for an oil storage depôt. The tidal range was about 18 ft. with 29 ft. of water at low water ordinary spring tides. The length of the new approach was 560 ft., with a width of 18 ft., the length of new deep-water berthage being 420 ft., with a deck width of 40 ft. throughout. The total deck area of the new works was approximately 31,100 sq. ft. The contract was let in August, 1920, and the works were estimated at 80,000*l*., or 2*l*. 11*s*. 5*d*. per square foot of new wharf accommodation obtained. Figs. 4 and 5 illustrate the duplex travelling pile-driving frame used by Messrs. Mowlem and Company on this contract.

The second undertaking (see Fig. 6) was very similar in character, representing as it did the extension of existing wharf facilities. The new extensions are shown unshaded in the figure. In this case the works were situated on the south bank of the river, and were carried out in creosoted Oregon and pitch pine, with steel superstructure. The tidal range was slightly greater

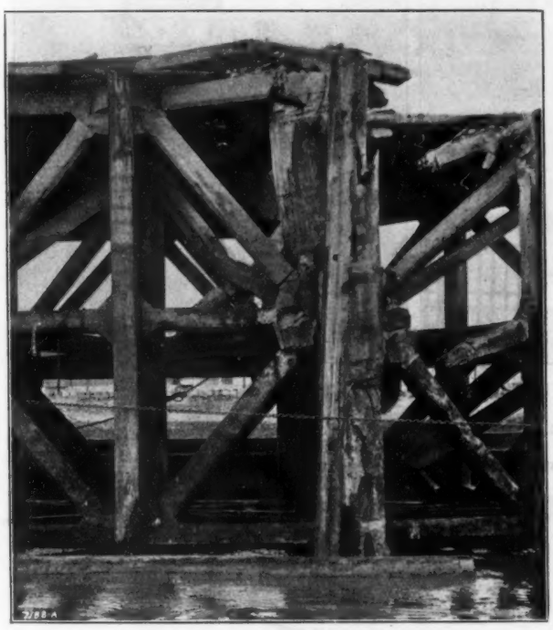


FIG. 1. REINFORCED CONCRETE QUAY DAMAGED BY 6000-TON STEAMER.

FIG. 2. TIMBER QUAY DAMAGED BY 11,000-TON STEAMER.

fully to appreciate its utility and economy, and where to realise its limitations.

He has formed the conclusion that, under post-war conditions, it is not always the most suitable type of construction to employ for deep-water tidal berths. This will be regarded as a sweeping assertion, and it is open to much criticism by members of our profession who are devoted adherents to the school of *béton armée*. It is, therefore, proposed in this article first to advance arguments and then to support them as far as possible with such facts as are available.

It is first necessary to limit consideration of this problem to definite geographical limits—since, as applied elsewhere, the arguments here advanced would admittedly be unsound and misleading. The arguments are, therefore, confined to the coast, rivers and estuaries of the United Kingdom, with their varying tidal range from 6 ft. to nearly 60 ft.

Tidal berths generally become impracticable in waters having a range at ordinary tides of much more than 25 ft. The rivers, coasts and estuaries within this tidal range are subject generally to variable weather, fog, and tidal currents, and the structures forming tidal berths are therefore liable to heavy impact, beyond that experienced in docks, from shipping when berthing, and they are further liable to collision. In a busy river and estuary such as the Thames below London Bridge this is especially the case. In general, most deep water quay designs comprise piling as an essential her course in a fog. The collision was of the "stem-on" type, and the damage shows clearly in the illustration. It is difficult for any engineer to say to what extent such damaged work must be cut out and replaced. The work of cutting out reinforced concrete is hard and costly, while special plant in the form of shuttering, concrete mixers, &c., are required. The work of reparation takes a long time, and in consequence the period over which the berthage cannot be used is considerable.

The photograph Fig. 2 shows the result of a collision between a ship of 11,000 tons register and a timber jetty used for the same class of trade. The accident in this case was again due to a fog. The extent of the damage is clear and defined. The damaged work can rapidly be dismantled. No special plant is required for reconstruction and, the work of reparation being rapid, the period during which the jetty cannot be used is short.

As regards cost and rapidity of construction, the author's firm, as consultants, were responsible for two extensive deep-water berths constructed simultaneously in the Thames Estuary. Both works were commenced in the autumn of 1919, and were amongst the first marine works carried out by private enterprise following the conclusion of hostilities.

One undertaking (see Fig. 3) was situated on the Essex shore on the north bank of the river, and was carried out in reinforced concrete (Coignet system). It consisted of the extension of a deep-than in the preceding case, but with a depth of only about 17 ft. at low water ordinary spring tides. Owing, however, to the bad nature of the ground below the river bed the length of piles required was approximately the same. The length of the new section of the approach was 455 ft., with a minimum width of 8 ft. The length of the new deep-water berthage was 303 ft., with a width of 52 ft. throughout, and three splays were provided as shown in the plan. The total deck area of the new works was approximately 24,600 sq. ft. The contract was let on July 26, 1919, and the works cost 70,783*l*., or 2*l*. 17*s*. 8*d*. per square foot of new wharf accommodation obtained. The Main Quay extension is illustrated in Fig. 8, page 383.

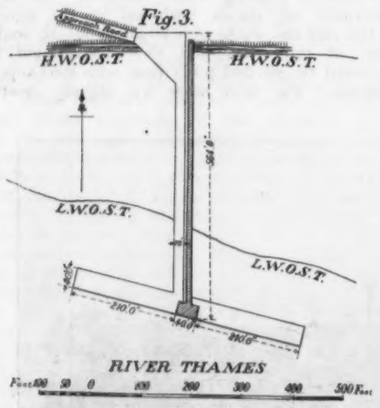
At first sight these comparisons appear to favour the use of reinforced concrete. The timber jetty, however, was completed on March 31, 1921, at which date the reinforced concrete jetty was less than half completed with some evidence that the original estimate was likely to be exceeded.

There remains, of course, the question of maintenance. It has been suggested that something in the nature of 10 per cent. per annum is required to maintain a timber jetty in the River Thames. This in the author's opinion is excessive. If neither the reinforced concrete or timber quay were used for their intended purposes, and they were immune from collision, the reinforced concrete structure would naturally be the more enduring. Subject however, to collision and damage by shipping as

such quays are, it is fairly obvious that the more economical proposition for the practical wharfinger is still the timber quay. These have acquired a bad name solely through the almost criminal negligence of their owners in allowing them to fall into decay.

An interesting example of reinforced concrete work exists in the new deep-water quay now under construction at Thames Haven for the London and Thames Haven Oil Wharves, Limited. Fig. 7 gives an idea of the type of construction shown in perspective. The general outline of the design was laid down by the author's firm and the Considere Construction Company, of 5, Victoria-street, S.W. 1, designed the reinforcement.

Fig. 3.



The cylinder type of construction has been selected, the cylinders being spaced at 30-ft. centres. The bracings, struts and walings have been designed so as to enable them to be pre-cast and these works, it is hoped, can be regarded as representing good modern practice in reinforced concrete for wharf accommodation in a tidal estuary. It will be noted that some saving in initial cost may perhaps be effected in this wharf by the reduction of deck area, the cylinders in the rear of the structure being carried to only a few feet above low water with rising struts to deck level on the quayside. The structure has been so designed as to permit of the full deck width being adopted if required at a later date, by continuing the superstructure in rear of the short access deck now provided for along the quayside. The quay has been designed to deal with the oil trade, and for this purpose the only deck required is really for the purpose of access to the ship, and for accommodating the pipe lines and handling the mooring ropes. The prime function of this berthage is to enable ships to come alongside in the open river and to be rigidly held there either while discharging or receiving oil cargoes. A minimum depth of 30 ft. at low water will be secured.

In the design of deep water quays the conditions are so varied that anything like an analysis of cost is misleading. It appears, however, that for ocean-going shipping present-day costs in the Thames vary from 50*l.* to 200*l.* per foot run, and recently in connection with preparing Port of London licence application plans for a proposed cold-storage jetty involving some heavy dredging, the estimated cost exceeded the latter figure.

In all designs for tidal deep-water quays the following requirements must be kept in mind:—

(1) Good facilities for mooring vessels.
(2) Rigidity of structure.
(3) Immunity from damage.

It is of convenience to deal with the second and third points first. As regards "rigidity" of structure, design has to be governed principally by experience, and we frequently have to deal with the problem of berthing ships in the Thames which, when laden, represent a gross weight of 35,000 tons. When alongside, wind pressure and tide pressure can be calculated, but these stresses are negligible compared with those sometimes caused in berthing a ship, and these latter stresses are, unfortuntely, not calculable. Where reinforced concrete is adopted wide spans coupled with the "cylinder" type of construction probably represent the best practice to-day. Beyond this generalisation, however, the question of rigidity is one which must be left to the individual engineer guided by his experience.

Immunity from damage is a big problem. Assuming that adequate fendering is provided, there remains the liability of serious damage from a large ship due to impact from berthing. In relatively protected tidal waters with tidal ranges such as Antwerp or Rotterdam, this risk is reduced to a miminum if the ship is carefully handled.

In the Thames Estuary, however, where relatively greater exposure and fast tides have to be dealt with, if the berth is of lesser length than the ship, it is essential that the ship, whether assisted by tugs or not, should present a definite angle to the face of the berth in coming alongside, since there is no "flexibility" of position open to her as in the case of long continuous quay. Many deep-water berths consist of a jetty head and dolphins, and the latter are therefore exposed to severe impact from either the port or starboard bow of the ship when berthing, and experience shows that this class of berth is tending to become less suitable for the growing size of ships seeking berths in the open river outside the London Docks.

The first point enumerated above, however, principally merits attention, viz., "Good facilities for mooring." The author believes this to be the most difficult requirement to meet when dealing with large vessels in a tideway on a site exposed to heavy weather and with a long "fetch." This question must be considered from both the marine and civil engineering points of view. In one recent case designs were prepared for a continuous quay frontage some 1,350 lineal ft. in length. The range of tide was nearly 20 ft., and the mooring of large ships against such a continuous quay face was considered to present great practical difficulties. It was felt that the "spring" ropes could be dealt with, but that the bow and stern ropes would have to be increased in number and carried at awkward angles to compensate for the rise and fall of tide. There appears to be some doubt also if a ship so moored could be regarded as sufficiently held against the jetty. Unless this can be secured delays in loading or discharge will occur. In the case of a jetty and dolphins, as the ship's stem and stern generally project beyond these the bow and stern ropes can be carried ashore, a perfectly satisfactory method where it can be adopted. In all designs co-operation with officers of the mercantile marine as to lay-out is essential.

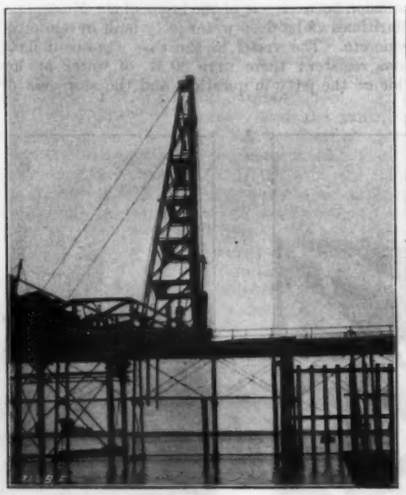
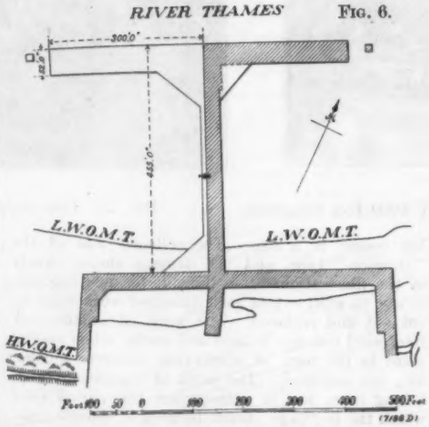


FIG. 4.

FIG. 5.

FIGS. 4 AND 5. DUPLEX TRAVELLING PILE-DRIVING FRAME.

RIVER THAMES FIG. 6.



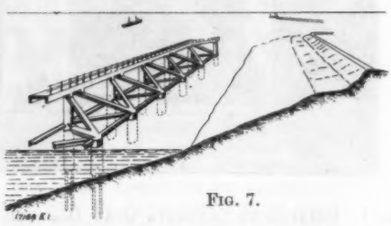


FIG. 7.

In the event of establishing entirely new industrial undertakings on the riverside the question of foundations is of importance. To some extent this is liable to be lost sight of by engineers who are, perhaps, too inclined to deal only with the problem from a purely technical point of view, and as one presenting technical difficulties only to be overcome. The practical engineer, however, should at all times bear in mind the financial aspect of any industrial undertaking, and wherever bad foundations can be avoided a corresponding large capital expenditure can generally be saved on which otherwise a large sum of interest has to be set aside yearly, resulting in a big and permanent handicap to economical production. In one such case a wrong choice of site resulted in excess expenditure of approximately 225,000*l.*, nearly one-quarter of the whole cost of constructional work. In the case of factories on the riverside, where the ground is bad there has been too much tendency to seek for small economies by placing the site of factory buildings as close to the river and wharf accommodation as possible. In many cases the subsequent working of the factory has shown this to have been an initial error, as the normal rate of interest on the excess cost of foundations often proves to be a greater charge than double handling and trucking or conveying the raw

or finished materials by more modern methods. In another case the foundations of the factory building and warehouses were so bad that, although the principal vertical members had been carried on piling, the cills and flooring of the factory subsided throughout a large section of the factory buildings, and the intake and outfall works were affected.

On one site the author's firm was requested to advise on the question of increasing the wharf area. This wharf was some 600 ft. long, built into the river with two return ends, and it had been suggested by the owners of the factory that the enclosed area might be reclaimed. The wharf was constructed in 1905, and subsequently several attempts were made to fill in the area by the dumping of solid material. This was abandoned when indications were obtained that if dumping were continued the lateral stresses on the existing wharf might cause the latter to collapse outwards. The actual area of reclamation was in all about 102,000 sq. ft., and from a casual observation this reclamation appeared a simple problem. Borings were originally taken over this ground in 1905 and showed uneven strata and bad ground. One of the borings was fairly representative of the bad nature of the ground. This boring gave the following results :—

0 ft. to 15 ft. chalk (artificial tip).
At 20-ft. depth, clay.
At 25 ft. depth, peat.
At 30-ft. depth, old empty pipes.
At 35-ft. depth, soft drab clay.
At 40-ft. depth, very moist clay.
At 45-ft. depth, Thames ballast.

The Thames ballast was by no means at a consistent level, as landwards of this boring red sand and clay were met with, the ballast probably disappearing altogether with the clay and sand deposits resting on the underlying chalk. The situation was further complicated by the varied nature of the waste materials with which spasmodic attempts had been made to recover this ground.

Any attempt at a solid fill would have required an elaborate retaining wall with piled foundations carried right down to the ballast (or to the chalk), as the lateral earth stresses set up would have been high and increased by the normal wharf load, which in this case was as high as 10 cwt. per square foot. The cost of doing this was estimated to be 122,160*l.* and the scheme as it stood had, therefore, to be entirely abandoned. To pile the area all over and construct light staging would have cost at least 50,000*l.*

It was then decided to test the area with a few trial piles, which duly confirmed these estimates, and as a result the whole idea of reclamation was abandoned—a classic example of an error in the initial selection of a factory site.

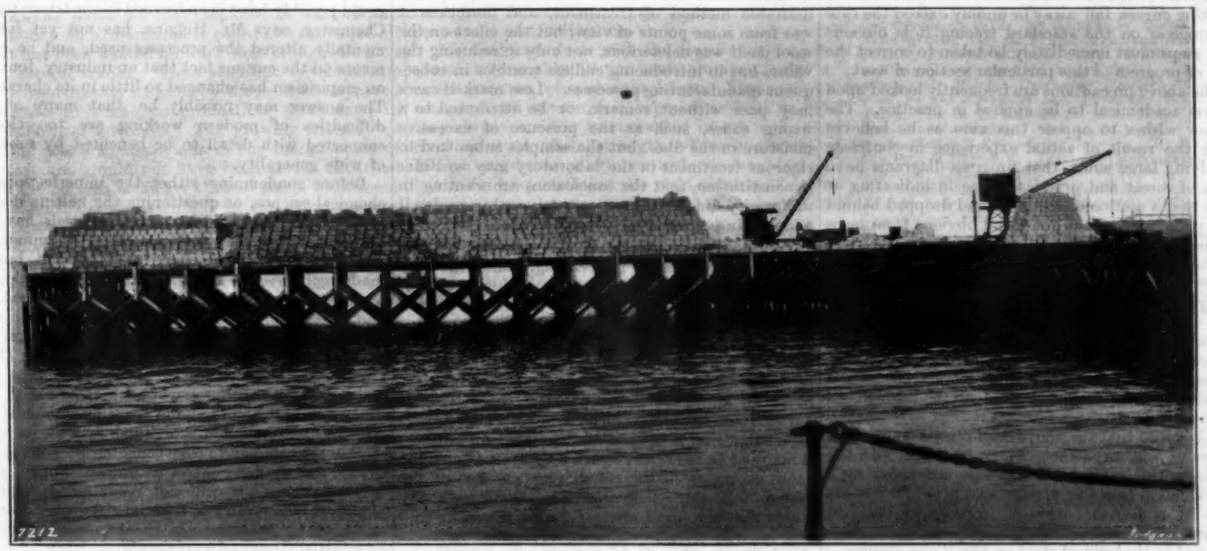


FIG. 8. EXTENSION OF QUAY AT EMPIRE PAPER MILLS.

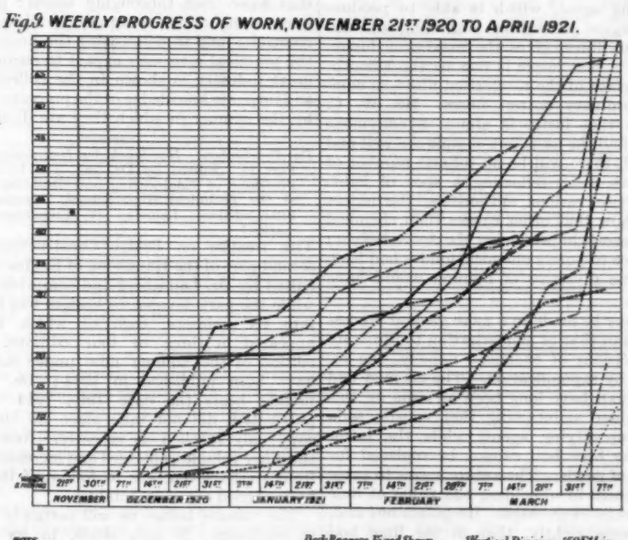


Fig.9. WEEKLY PROGRESS OF WORK, NOVEMBER 21ST 1920 TO APRIL 1921.
NOVEMBER
DECEMBER 1920
JANUARY 1921
FEBRUARY
MARCH
NOTE.
C.I. Pile Caps Fixed, Shown ____ Vertical Division - 5 Caps.
C.I. Bollard Caps - - ____ D° - 1 Cap.
R.S. Joists - - ____ D° - 100 F.t Lin.
Transoms - - ____ D° - 100 F.t Lin.
Walings - - ____ D° - 100 F.t Lin.
Deck Bearers Fixed Shown ____ Vertical Division - 150 F.t Lin.
Diagonals - - ____ D° - 200 F.t Lin.
Kerbing - - ____ D° - 20 F.t Lin.
Filling Pieces - - ____ D° - 20 F.t Lin.
Fenders - - ____ D° - 30 F.t Lin.
Decking - - ____ D° - 300 Sq. Feet.

One important point in connection with the carrying out of river contracts is the keeping of records in regards to the progress of work. The necessity for such records cannot be emphasised too much, and the cost of keeping them is negligible when compared with the great reductions in labour charges which follow.

One regrets that, owing to the special nature of marine work, delays are likely to occur in construction owing to unexpected causes being encountered, such as abnormal weather, loss of falseworks by collision, &c., and, as time is usually the essence of the contract, any undue delay must be corrected at once and lost time made up for if possible. This can only be done by maintaining a complete series of progress diagrams which can seldom be kept in too great detail. In cases where the works are being carried out by a contractor, the engineer and the contractor should prepare together a definite programme of work, and a time-table, and when the progress of the work falls behind this standard rate, a conference between the consulting engineers, the principals, the contractors, the resident engineer and the contractors' agent should always take place.

The author has found this policy sometimes looked upon as unnecessary by both clients and contractors in the early stages, but if the result as to time and cost is to give satisfaction to all concerned, no delay, even if apparently unimportant, should be allowed to pass without close and immediate examination as to cause.

It is well known there are two methods of keeping progress diagrams, namely :—

(1) By preparing skeleton drawings showing all units of the work, which latter are marked off or coloured as they are finally fixed in position, or

(2) By listing all the units of construction and preparing curves or "graphs" for each unit.

The latter method is to be preferred for marine works of any extent since the principal objection to the first method is the very elaborate series of drawings required; such drawings have to be of special character, since the contract drawings themselves, though indicating the exact nature of the work, will not necessarily repeat any uniform section of the work, more often than is necessary for constructional purposes, whereas progress diagrams

must show every unit as often as it occurs, whether it is concrete block, pile, walling, bracing, diagonal, deck bearer, girder, &c. The second method has also the advantage of enabling whoever is responsible for maintaining the diagrams up to date to plot the principal curves on one sheet, and although varying scales invariably have to be applied to each curve. A standard tracing showing the correct rate of progress for each unit, can be superimposed from time to time over the actual records, and if the working curves fall away or unduly exceed the rate of progress on the standard tracing it is obvious that steps must immediately be taken to correct the rate of progress of this particular section of work.

The above precautions are frequently looked upon as too academical to be applied in practice. The author wishes to oppose this view as he believes from the result of actual experience in contracts involving large sums, that progress diagrams have been of direct and practical value in indicating at once that a section of the work had dropped behind the remainder, a fact not at all obvious from mere inspection.

The consultant in making periodical inspections of work can thus go on the site with some idea of progress in his mind, and is often able to discover the causes of delay with greater facility. The important point to remember is that the progress diagram indicates beforehand where delay may be expected in the future and not merely the extent to which the works are behind at the moment of inspection.

It is hoped that the above brief *résumé* on progress diagrams will serve the purpose intended, and the notes on this subject are therefore concluded by a reproduction (see Fig. 9, page 383) of actual records kept by a resident engineer in 1920 to 1921, in connection with an extensive deep-water pier constructed in timber and steel on the River Thames.

LITERATURE.

Bleaching. Being a Resumé of the Important Researches on the Industry Published during the Years 1908–1920. By S. H. HIGGINS, M.Sc., Head of Research Department, Bleachers Association, Limited. Manchester: University Press. London: Longmans, Green and Co. [Price 10*s.* 6*d.* net.]

SINCE the textile fabrics constitute the raw material for one of our most important industries, a comprehensive monograph referring to one of the chief operations to which these fabrics are submitted, forms a welcome addition to our industrial literature. The author of the present volume confines his attention to the subject of bleaching—a definite branch of the chemistry of cellulose—and his object is to discuss the experimental researches bearing on the bleaching industry that have been published in recent years. The technical processes of bleaching, as practised in the course of manufacture are outside his programme, which deals with the progress of research rather than that of application. Many chemists have sought to improve the technic or to explain the complicated reactions that take place in practice, and if the author could have prepared a consecutive statement indicating continuous progress, the interest of the book would have been greater and its value better appreciated. We are too often left in doubt as to the proper method of proceeding under given circumstances. The author is not prepared to take the responsibility of indicating preference or rejection of particular conclusions. Doubt and controversy are too often encountered, and in the absence of agreement in chemical experiment, experience has to take its own way undirected by scientific deduction.

The reasons for this diversity of opinion are not far to seek, and certainly reflect no blame on modern research. Raw fibres, whether of animal or vegetable origin, contain besides cellulose, many ingredients of complex and undetermined constitution, and these it is the object of bleaching to remove, or to reduce to a minimum. Such constituents are minute in amount, but differ greatly in percentage, making one sample essentially different from another. Variations of climate and of soil materially influence the structure of vegetable fibres that are subsequently submitted to the same mechanical and chemical treatment in the processes of bleaching. Animal fibres both in strength and character are affected by the treatment of the stock, and the precautions adopted to protect the animals. The effect of the ingredients used in sheep dip in South America on the marketable value of the wool may be an extreme case, but it illustrates the numerous causes that are at work in promoting that uncertainty of output to which chemical analysis is applied. In that case, a mixture of slaked lime and caustic soda was considered a desirable method of treatment, and doubtless it was from some points of view, but the effect on the wool itself was deleterious, not only in reducing the value, but in introducing endless troubles in subsequent manufacturing processes. Less marked cases may pass without remark, or be attributed to a wrong cause, such as the presence of excessive moisture in the fibre, but the samples submitted to rigorous treatment in the laboratory may so differ in constitution, that the conclusions are wanting in uniformity and form an untrustworthy guide if adopted in practice.

To quote instances from the treatise we may mention the process of mercerising. Must the fibre be kept under a condition of strain during part of the process, and to what extent might the mechanical treatment be replaced by chemical action? And if, as some assert, a long staple cotton is necessary for success, is this success due to a change in the chemical or molecular nature of the cellulose, or to an alteration in its physical characteristics induced by the initial processes to which it has been submitted? Among the multitude of advisers it may not be indiscreet to ask whether we know the cause or causes of the peculiar appearance of the fabric following mercerisation. One authority states that the fibres untwist during mercerisation, and re-twist often in opposite directions, and that the lustre produced depends largely on the reflection of light by the swollen and re-twisted fibres. From this hypotheses the conclusion is drawn, that the mercerising agent, which is able to produce the highest degree of swelling, shrinking and untwisting of the fibres, gives the maximum lustre. Another view is that lustre is due to the smoothness of the surface of the mercerised fibres as compared with ordinary cotton fibres. Mr. W. C. Balls declares that lustre is almost synonymous with twist. If all the hairs in a sample are well and evenly twisted, there will be an infinite number of convex surfaces, each reflecting a spot of light. In quoting these various authorities, the object has been to show that other causes than chemical change may operate in producing the desired effect; but if adherence to purely chemical guides had been strict, the same diversity of opinion would have been apparent.

Reference may be made to a more general process in bleaching than that of mercerisation to illustrate the varied decisions of chemists, namely, the removal of wax by saponification. The chemist and the practical man have long been at issue on this point, the former maintaining that caustic soda is the best saponifying agent, while the latter insists that the lime boil cannot be replaced for certain classes of goods. The author seems to agree with the bleachers in upholding the value of lime boiling, at least in some cases. He points out and, as it would seem rightly, that in the lime boil and "sour," the unsaponifiable portion of the wax and free fatty acids are left on the fibre, and in the lye boiling a soap is readily produced by the alkali and the fatty acid, resulting in the emulsification and elimination of the unsaponifiable portion. The matter, however, cannot be so simple as this conclusion implies, or there would have been no controversy. The difference of opinion probably arises from the various classes of goods and their variety of composition, to which the method is applied.

It seems possible that those who turn over these pages, in which are summarised so many valuable papers and such varied experience, will ask themselves of what use is chemical analysis in forwarding the practice of bleaching, in what ways has it benefited the industry, either in standardising methods or in devising an improved technique? Knowledge comes but wisdom lingers, and the author, than whom none has been more energetic in testing processes and perfecting methods, is not without sympathy for the bewildered and distressed operator. In his first paragraph, he asserts prominently that the bleaching industry was founded in empiricism "because then, as now, chemists had not accurately determined the nature of the substances composing the materials undergoing the bleaching. . . . The methods the bleacher uses are the results of accumulated experience, and practical experience has taught him more than could possibly have been learned in the laboratory," Chemistry, says Mr. Higgins, has not yet fundamentally altered the processes used, and he comments on the curious fact that an industry founded on empiricism has changed so little in its character. The answer may possibly be, that many of the difficulties of modern working are too closely connected with detail to be benefited by schemes of wide generality.

Before condemning either the imperfections of chemical science, or questioning the halting deductions of the experimenter, two essentials have to be remembered, first that a method recommended may be ideal from the chemical standpoint, but be inadmissible on the ground of economy, for though a chemical agent may be energetic in its action, and certain in its effect, it has to compete with processes that long experience and continual practice have rendered both familiar and uncostly. There are those who will maintain that good boiling will ever prove the cheapest way of getting rid of the impurities in the cloth and of ensuring a good white. And secondly, though a method may be demonstrably scientific and prove economical, if it require careful and skilled control to prevent injury, such as "tendering," it will not recommend itself to bleachers who prefer to take no risks when having to place the operations in the hands of unskilled and partially trained workpeople.

The author's work will be particularly valuable in preventing the repetition of many experiments that have been thoroughly tested: in suggesting lines along which progress is likely to reward research; and in delineating the limitations which the practical man may expect to encounter. Very great industry is shown in the collection of facts and intimate knowledge of the processes is evidenced by the manner in which they are discussed.

Der Brückenbau. Handbuch der Ingenieurwissenschaften. Part II. Edited by Dr. Ing. TH. LANDSBERG, late Professor of Engineering and Building Construction at the Technical High School, Darmstadt. Vol. I. Fifth edition. Leipzig: W. Engelmann. [Price 45 marks.]

THE treatise on Bridge Construction forms the second part of the Handbook of Engineering Science, edited by Dr. Landsberg and comprising five parts, while the part devoted to bridges was itself divided into six volumes, each of which had already appeared in three or four editions. The new edition of the volume now under notice was to have been published in 1914; Dr. Landsberg's preface bears the date July, 1914. The actual publication did not take place till 1917, and our copy only reached us recently. New editions of the other volumes, enlarged and increased in number from six to seven, are to follow, if the scheme is to be carried out in its totality.

The volume before us will certainly be welcome to engineers. It only deals, in its three main sections, with I. Bridges in General, II. Massive Stone, Concrete and Ferro-concrete Bridges, and III. the Building and Maintenance of Stone-Arch Bridges. Important additions have, in the new edition, mainly been made to Section II, written by Professor M. Foerster, of Dresden, and Section III, by Professor G. Mehrtens, Professor Foerster's predecessor at Dresden. Dr. Landsberg himself has compiled the general section I. The book simply teems with data, tables and figures and, though many of the 355 text figures are on a small scale, the excellent type and paper facilitate their study. At the end of 545 pages of text, large octavo, we find a special literature list, an alphabetical index, and an atlas of XXII folded plates to which references are made in the volume. The literature list just mentioned, which tabulates papers on special bridges and their structural features or history, is in addition to other long bibliographies embodied in the sections and to the copious footnotes, and is

arranged as to journals. We only regret the absence of cross-references to this list in the text. One of the special commendable features of the volume is the large number of comparative tables relating to structures of particular types.

Aluminium and its Alloys. Their Properties, Thermal Treatment and Industrial Application. By C. GRARD. Translated by C. M. Phillips and H. W. L. Phillips, B.A., A.I.C. London: Constable and Co., Limited. [Price 17*s.* 6*d.* net.]

HOWEVER much we may deplore the expenditure of money on armaments, it cannot be said that all of it has been wasted on work that brought no gain to peaceful trades. Great scientific developments have been directly inspired by the need for improved materials in armament production, particularly in metallurgical advances. The growing industry of special steels so important in the manufacture of motor cars, would not have been so far advanced had the success of nickel chrome steels for armour plates not drawn attention to the improvements which could be effected in steel by alloying and stimulated investigation in the effort to discover still better compositions. And at the present time the development of airship construction has brought into being a demand for light alloys with the greatest possible strength, and the search for improvement has revealed for the first time facts concerning the alloys of aluminium of great scientific importance, and of equally great technical significance. In the scientific laboratories of the allies work was carried out during the war, and money was lavished on investigations which are now for the first time being published, and which indicate in a manner quite unassuming the magnitude and the far-reaching nature of the efforts which brought victory. And it is an added gratification that these efforts mark also a step in the advance of peaceful progress.

Captain Grard, whose scientific work is already well known to metallurgical students, has collected together in "Aluminium and its Alloys" the experiments which were collectively undertaken by the French Aeronautical Commission in conjunction with several manufacturers of aluminium, to investigate the properties of aluminium alloys and especially to determine the peculiar action of alloys containing magnesium which age-harden after heat treatment. It is not a text-book in the accepted sense of the term, but rather a laboratory notebook packed with detail experiments and facts systematically undertaken and carefully checked by the co-workers amongst themselves. It is a reference volume which will be studied again and again by workers in this field.

Cold-working aluminium increases its hardness up to about 50 per cent. reduction in area, after which spontaneous annealing seems to prevent further cold work from affecting the physical properties, and annealing brings back the properties to normal again. It is an advantage to expose the metal to great degrees of cold work and then to anneal at an appropriate temperature. This makes the metal more ductile without impairing its strength, and it also seems to prevent the occurrence of the disintegration which is known in Britain as season cracking, and is naturally of economic importance.

The properties of numerous cast alloys were examined, and the strength and hardness determined at high temperatures, and the conclusions which can be drawn from the results indicate that there is no advantage in adding more than 8 per cent. of copper in castings which have then a strength of about 7 tons and an elongation of $\frac{3}{4}$ per cent.

The duralumin alloys, that is alloys containing a small proportion of magnesium and silicon with generally about 4 per cent. copper in addition, have been the subject of many experiments, with the object of determining the best treatment and annealing with the highest strength. Heating to boiling water temperature hastens the ageing effect very considerably, accomplishing in a few hours the same effect as many days at ordinary temperatures. Equally important is the definite reply to the question whether the hardening effect is permanent which affects the confidence of its application. About an alloy which hardened at ordinary temperatures after quenching there has been the feeling that perhaps after a longer interval a reverse change might set in which by reducing the strength would destroy its utility. Captain Grard records, however, that samples which gave 14·6 tons yield, 24·1 tons maximum strength and 14·5 per cent. elongation when passed test, still possessed after an interval of time which varied from one to three years, an average yield of 16·5 tons, a strength of 26 tons and an elongation of 15 per cent. to 20 per cent. Within this interval of time therefore the mechanical properties were still improving, and the results strengthen the assurance that the improvement is a permanent and lasting one.

The final part deals with the aluminium bronzes containing roughly 10 per cent. aluminium and a small addition of nickel and iron. These alloys are resistant to corrosion, especially of sea water, they do not oxidise when heated in air, and they rival steel in their strength. Tensile strengths as high as 50 tons per square inch can be obtained, but in its best condition the yield-point is 17 tons, the maximum stress 36 tons and the elongation 34 per cent. An even better alloy contains in addition to 10 per cent. aluminium, 4·4 per cent. iron and 3·55 per cent. nickel, and its mechanical properties, after annealing at 900 deg. C. yield-point 22·86 tons, maximum stress 47·62 tons, and elongation 26 per cent. There would seem to be a big field for the development of such alloys in engineering work.

The book under notice is really packed with useful information, and the author and translators deserve the thanks of all engineers and metallurgists for the excellent work they have done.

BOOKS RECEIVED.

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"LINEAR" RESISTANCE HEATERS.—The term "linear heating" is due to a Swiss engineer, Zweifel-Zwicky, of Bludenz, whose devices have been taken up by the Oerlikon Company. The linear heaters are uninsulated resistances consisting of iron band or wire, suitably covered in if necessary, which are stretched on porcelain insulators between terminal boxes. These heaters are intended for workshops and sheds, especially those which need not be heated during actual working hours, but have to be kept fairly warm over night. The design was first tried during the war, when owing to the dearth of material generally, the iron hoops of cotton bales were suspended over porcelain rolls in cotton mills and joined to the three-phase mains. The hoops were kept about 8 ft. above the floor, and sufficient experience was gained with them to justify technical adoption of the idea. In Austria uninsulated tapes and wires were tolerated; in Switzerland the authorities insisted on a protective covering, and the wires were placed in gas pipes or in flexible metal pipes and cases. The *Schweizerische Bauzeitung,* of March 11, illustrates some of these arrangements, such, for instance, as the mounting of the pipes along vertical posts between terminal boxes at the top and bottom. As the linear heaters are taken right through the rooms like hot water pipes, only a few short leads are required. Bedrooms and offices are also kept moderately warm on this plan.

RADIO-ACTIVITY.

AT the Royal Institution, on Saturday afternoon last, Sir Ernest Rutherford, F.R.S., delivered the fourth lecture of his course on the above subject.* The lecturer said that on the last occasion he had tried to explain the methods by which in the Montreal experiments he and Prof. Soddy had been able to ascertain the chemical properties of many radio-active bodies; and in particular of that extraordinary gas the radium emanation, although the amount available occupied only one-tenth of a cubic millimetre at standard temperature and pressure. They had succeeded, nevertheless, in determining its atomic weight, its spectrum, its density, and its boiling point. The next point of interest that arose was whether any rule or order could be found in the chemical properties of these great groups of transformable elements. Was there any connection between these and the corresponding properties of ordinary elements, and could any connection be traced between the chemical characteristics of successive members in a family and the type of radiation emitted during the transformations? The properties of successive members often differed widely. Thus radium was a solid with marked chemical affinities, whilst the emanation was a gas belonging to the argon group and devoid of chemical properties. A change of the most complete character in the chemical properties was thus effected in a single stage.

It had now been definitely established that the chemical atom in some respects resembled the solar system. The central part or nucleus had concentrated in it almost the whole of the mass, and was exceedingly small, as compared with what we were accustomed to call the diameter of the atom. This nucleus was, moreover, charged with positive electricity, and was surrounded by what had sometimes been called planetary electrons, which, relatively speaking, extended to a very considerable distance from the centre of the atom. In the normal state the complete atom was electrically neutral, so that the number of planetary electrons must then be sufficient to neutralise the excess of positive electricity in the nucleus. As was now known, electricity was atomic in character, and an electron was simply an atom of negative electricity. Thus in the case of the oxygen atom which was represented diagrammatically and not to scale in Fig. 18, the excess of positive charges at the centre of the atom was eight units, which in the neutral atom was balanced by eight electrons arranged round it as indicated.

Through Moseley's work with X-ray spectra we now knew what was the excess of positive electricity at the nucleus of each of the chemical atoms. The amount ranged from one unit in the case of hydrogen, two units in that of helium, and so on up to uranium, the heaviest known atom, which had in its nucleus an excess of 92 units of positive electricity. Corresponding to this the surrounding system of planetary electrons also consisted of 92 units. The whole of the properties of an atom were therefore fixed and defined by the magnitude of the nuclear charge. This followed because the atom was an electrical structure held together by electric attractions. The positive charge at the centre controlled accordingly the number and distribution of the planetary electrons which surrounded it, and these were in their turn responsible for the ordinary chemical and physical properties of the atom. It followed accordingly that the number 92 defined all the essential properties of uranium. It had, however, been found that in the case of certain elements, *e.g.*, chlorine and mercury, although all the atoms had the same nuclear charge, or excess of positive electricity, the nuclei might nevertheless differ in mass. Since, however, the excess of positive electricity in the nucleus defined the properties of the atom, these two different kinds of atom had the same chemical or physical properties, or differed only to a very slight extent. Such atoms were known as isotopes.

Let us, Sir Ernest proceeded, apply this theory to the transformations of the uranium group of radio-active elements as set out in Fig. 19. Here it would be seen that when Url disintegrated to yield UrX_1 an α particle was emitted. These α particles, as already mentioned, were atoms of helium carrying two positive charges of electricity, and like the β rays emitted in the next stage of the transformation came from the interior of an extraordinarily minute nucleus. It was evident, therefore, that the nucleus contained both helium and electrons, and was, in fact, a little world in itself. Its resultant positive charge was due to the collection comprising more positive charges of electricity than electrons.

In Fig. 19 each element was characterised by its atomic number, which could be considered as the order of an element when ranged according to its atomic weight, or more fundamentally as the excess of positive charges of electricity in its nucleus, which could be determined directly from the X-ray spectrum of the element. Uranium had an atomic weight of 238·2, and X-ray analysis showed that in its nucleus the number of positive charges exceeded the number of electrons there by 92: so that as indicated in Fig. 19 its atomic number was 92. The α particle expelled in the disintegration to UrX_1 carried two positive charges of electricity and, being an atom of helium, its atomic weight was 4. Hence the nucleus of UrX_1 contained two fewer positive charges than that of Url and its atomic number was accordingly 90.

FIG. 18.

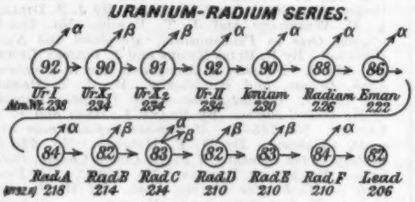

URANIUM-RADIUM SERIES.
92 90 91 92 90 88 86
Ur I. UrX1 UrX2 Ur II Ionium Radium Emanation
At.Wt. 238 234 234 234 230 226 222
84 82 83 82 83 84 82
Rad A Rad B Rad C Rad D Rad E Rad F Lead
(P0214) 218 214 214 210 210 210 206

FIG. 19.

At the same time its atomic weight was 4 units less than that of its parent. At the next stage of the transformation, in which UrX_2 was formed, a β ray was emitted from the nucleus, with great energy and at a very high speed. The β particle being an electron had a mass equal to only $\frac{1}{1845}$ that of the hydrogen atom, so that its loss did not, to a first order of approximation, affect the atomic weight. Hence UrX_2 had the same atomic weight as UrX_1 but the loss of the electron increased the excess of positive electricity in the nucleus, so that the atomic number of UrX_2 rose to 91, and its chemical properties were entirely different from those of its parent. In the next change a β-ray was again expelled, and the atomic number was thereby increased to 92, which was the same as that of the original body. Thus as the result of three transformations we got UrII, which had the same atomic number as UrI and was thus an isotope of that element, with an atomic weight 4 units less. It had, in fact, proved impossible to separate the two by chemical means, and would probably remain so. The law governing successive transformations, it would be seen, was that when an α particle was emitted the atom dropped two units in its atomic number and 4 units in mass; whilst when a β-ray was emitted its mass was practically unchanged, but the atomic number was increased by 1 unit. Following the different changes through, it would be seen that radium ought to have 88 as its atomic number, whilst its atomic weight should be 226. The X-ray spectrum of the metal had now been obtained and showed that the atomic number was 88, as it should be, and its atomic weight as determined by the chemists was found to be 226 to the nearest unit.

Figure 19 showed that Rad F. (Polonium) was the last radioactive member of the family, and transformed into a body with an atomic number 82 and an atomic weight of 206. Eighty-two was also the atomic number of ordinary lead, which was credited with an atomic weight of 207. The same atomic number occurred twice further up the series, and it had been shown that radium B gave exactly the same X-ray spectrum as lead.

Exactly the same state of affairs was found to occur with the thorium series. Meso-thorium had the same atomic number as radium, but quite distinctive radio-active properties. The thorium emanation again had the same atomic number as the radium emanation and the end member of the series was again a body with the properties of lead. It would be seen that if we knew the type of radiation given out in each change, we could by the simple rule above given find, straight away, the atomic number of each member of the series and also its atomic weight to an accuracy of at least one part in 400 to 500.

The foregoing conclusions, Sir Ernest continued, were summarised in Fig. 20 (page 387). Here all elements lying along the same horizontal line had the same atomic number and belonged to the same periodic group, being isotopes of each other and of the ordinary elements printed on the extreme left. Thus all the three emanations were chemically and physically identical though very distinct from each other in their radio-activity properties.

Before the importance of the atomic number was known, Russell, Fajans and Soddy, all three at almost the same time, had noted that the emission of an α particle lowered the position of a body in the periodic groups of the chemist by two places, and that the emission of a β particle raised it one place. It was found that ionium and thorium had the same chemical properties, and that the two could not be separated. Similarly radium could not be separated from meso-thorium, although these bodies were distinct in their radio-active properties. This appeared very strange when first discovered, but we now knew that though these bodies had identical atomic numbers their nuclei must differ in structure because they had different atomic weights, and on this structure depended the manner and rate at which the respective atoms exploded.

It was very clear from the foregoing that these losses of positive or negative charges which occurred when an atom exploded were intimately connected with the periodic law of the chemists. The whole system of periodic groups had now been thoroughly worked out, and from this it appeared that elements with atomic numbers equal to 43, 61, 75, 85 and 87 still remained to be discovered by the labours of the chemist or the physicist. Radio-active elements first made their appearance in group IV as isotopes of thallium, of which the atomic number was 81. The next atomic number was that of lead, of which a large number of radio-active isotopes were known. Although the periodic law had proved very elastic in the hands of intelligent chemists it was at the outset a shock to their feelings when first called upon to find places in their groups for all these new bodies. As shown in Fig. 20 the end products of the uranium and thorium chains gave two isotopes of lead having atomic weights different from that of ordinary lead. It was of interest therefore to discover whether the lead found in very old uranium and thorium minerals had the same atomic weight as ordinary lead of which the recognised atomic weight was 207·19 and the density 11·337. In the case of lead obtained from the uranium minerals at Joachimstal the lowest atomic weight found was 206·08, and the density was 11·280. The highest value for the atomic weight of lead extracted from thorite was 207·9. Taking the atomic weight of uranium as 238·2, there were eight α particles emitted before uranium-lead was reached, and the atomic weight of the latter should accordingly be $238·2 - 32 = 206·2$. Similarly in the transformation which ended in thorium lead, six α particles were emitted, so that thorium lead should have an atomic weight of $232·12 - 24 = 208·12$. These calculated figures agreed extraordinarily well with the values found by direct experiment. It was, moreover, of interest to note that this was the first case in which isotopes had actually been obtained separated from each other. Enormous energy had been expended in effecting a partial separation of the isotopes of

* Reports of the three preceding lectures will be found in our issues of March 10, March 17 and March 24, on pages 299, 331 and 380 respectively.

MACHINERY AND BOILERS OF THE GREA EAS

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COM

(For Descripti Page 3

Fig. 1.

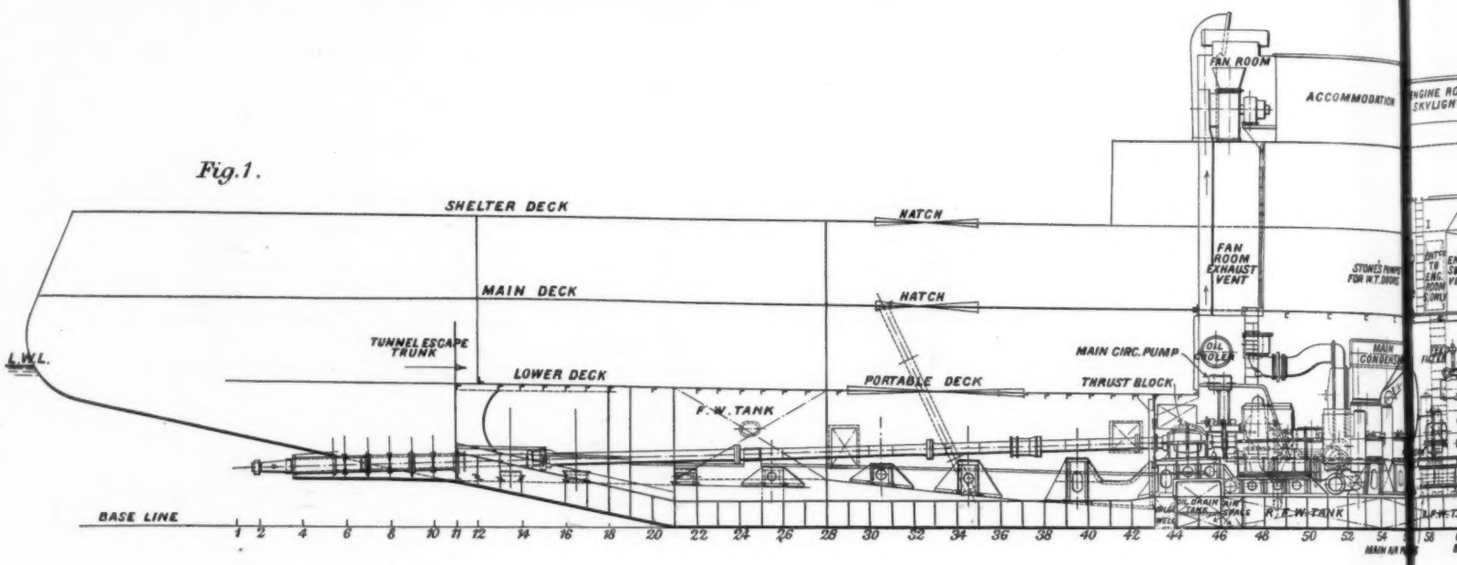


Fig. 2.

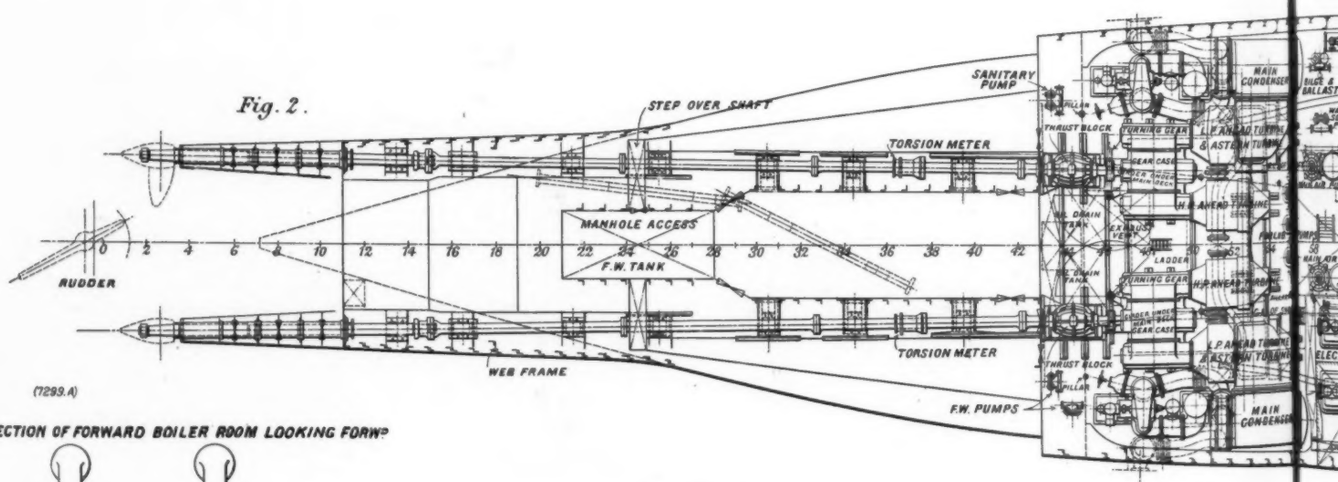


Fig. 5. SECTION OF FORWARD BOILER ROOM LOOKING FORW^D

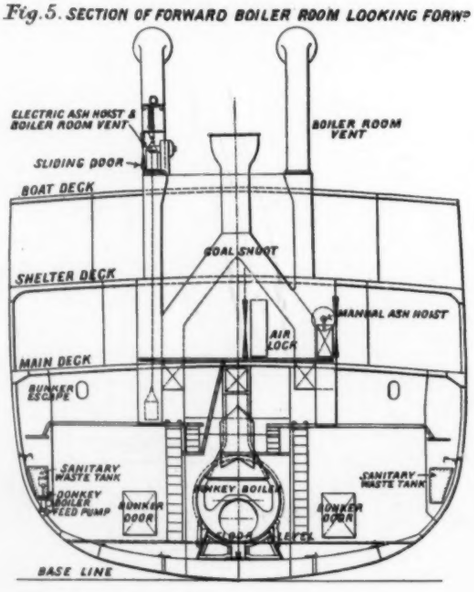


Fig. 6.
SECTION AT ABOUT FRAME N^o 45. LOOKING AFT.

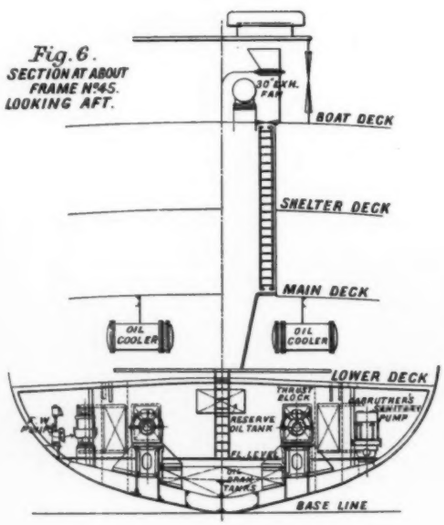
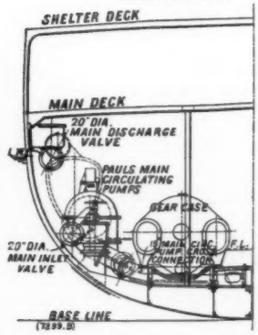


Fig. 7. SECTION AT ABOUT FRAME N^o 50. LOOKING AFT.



EASTERN RAILWAY STEAMER "MALINES."

G COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

Page 387.)

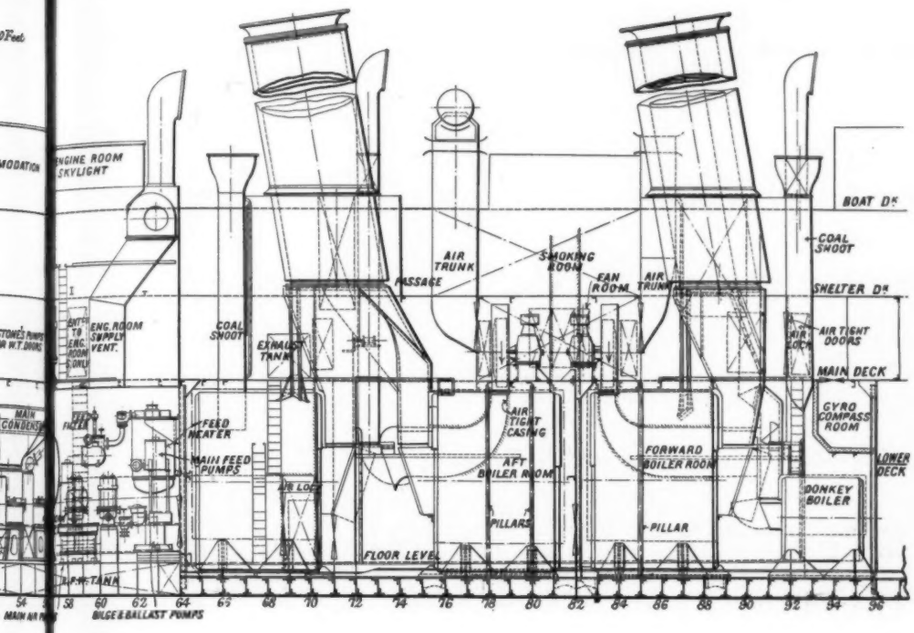
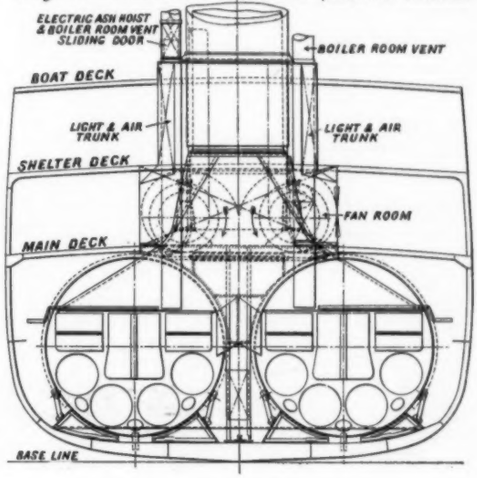


Fig. 3. SECTION AT AFT BOILER ROOM, LOOKING FORWARD.



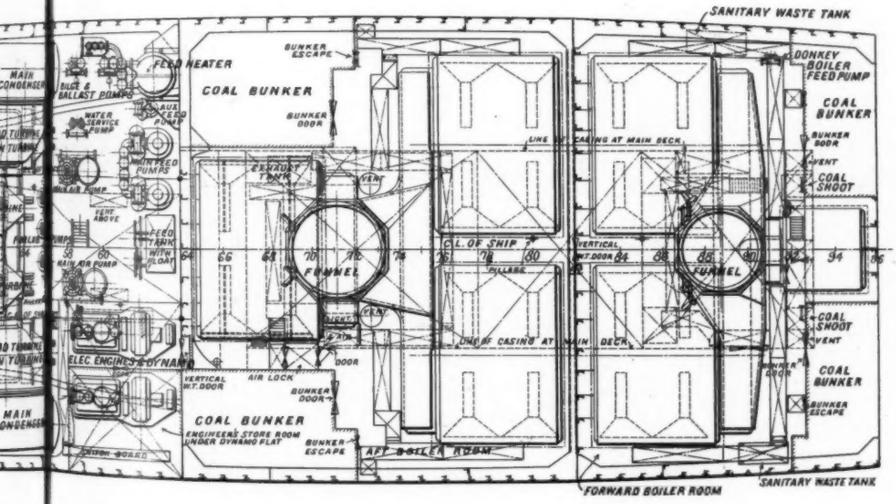


Fig. 4. SECTION AT AFT BOILER ROOM, LOOKING AFT.

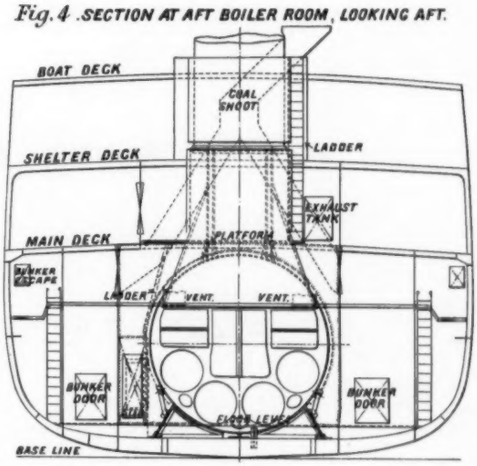


Fig. 8. SECTION AT ABOUT FRAME N° 58. LOOKING AFT.

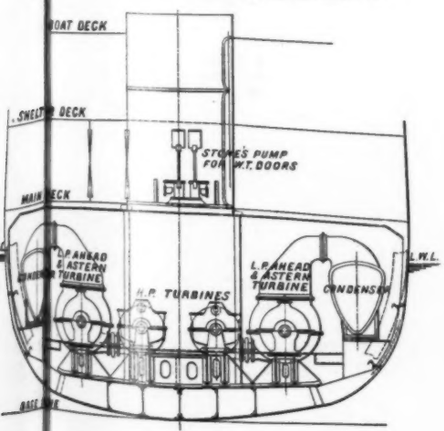


Fig. 9. SECTION AT ABOUT FRAME N° 58. SHOWING PUMPS.

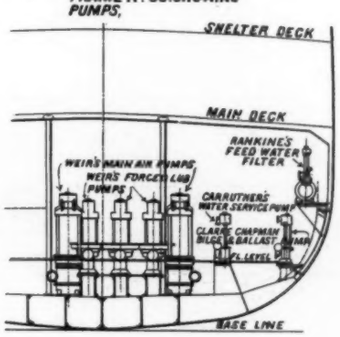
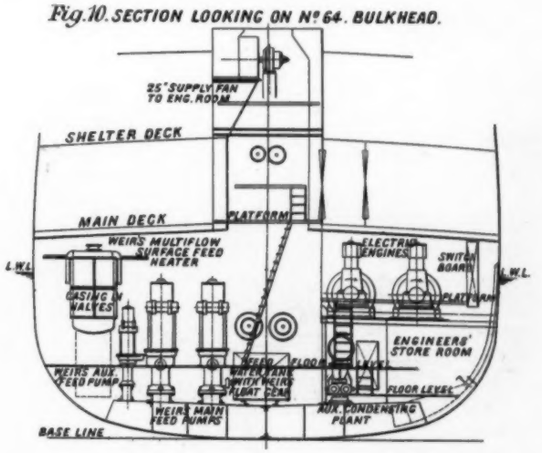


Fig. 10. SECTION LOOKING ON N° 64. BULKHEAD.



chlorine and mercury, but Nature had itself separated these two isotopes of lead. The question naturally arose as to whether ordinary lead was a mixture of these two isotopes? It was, the speaker thought, more probable that ordinary lead was a mixture of perhaps half a dozen isotopes.

The pitchblende of Joachimstal contains a very small amount of thorium. Ordinary thorium has an atomic weight of 232·12, but the atomic weight of the thorium separated from this pitchblende is 231·5, and it is probable that it contains a certain amount of ionium, which is chemically indistinguishable from thorium.

After the nature of the α-rays emitted by radium had been recognised, the problem arose of determining the number emitted per second. The α particles shot out by any one of the radioactive elements had in each case a certain definite range when they traversed air at standard pressure and

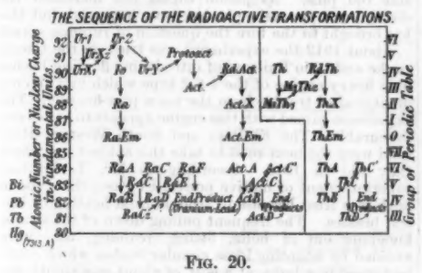


FIG. 20.

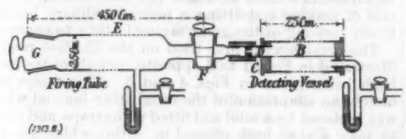


FIG. 21.

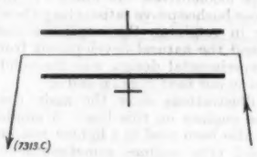


FIG. 22.

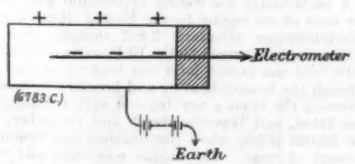


FIG. 23.

temperature. The particles passed actually through the molecules of the air and in doing so ionised them. The path of the α particles formed accordingly the core of a very fine cylinder consisting of a very large number of molecules thus ionised. The electrical effect thus produced was, however, just on the verge of what it was possible to detect by direct observation. The effect could, however, be magnified 10,000-fold by making use of an observation due to Townsend. The arrangement used by the speaker and Dr. Geiger, in their first attempts to count the α particles is represented in Fig. 21. In this E represents an exhausted vessel in which was fixed the radium from which the α particles were emitted. Occasionally the direction of emission was such that the particle found its way through the stop D into the detecting vessel on the left in which a low pressure of air was maintained. The outside surface of this vessel was maintained at a high positive potential relatively to the wire B. Townsend had shown that if this potential difference was almost the sparking potential, any ion liberated in the interspace between the wire and the walls of the vessel would acquire so high a velocity that it would ionise other molecules with which it collided and in this way the effect of a single ion could be magnified 10,000-fold. Hence every time an α-particle found its way into the detecting vessel the indicator of an electrometer connected up with B gave a "kick."

As matters were at first arranged, some three or four particles entered per minute and these were counted by the observer. Ultimately, however, Dr. Geiger developed a form of the apparatus in which the entrance of a particle was recorded photographically, and in this way as many as 1,000 records could be made per minute. A "string" electrometer was used in these experiments. It consisted of a fine Wollaston platinum wire, or a silver-coated quartz fibre strung, half-way between two plates as indicated diagrammatically in Fig. 22. These plates were connected to opposite poles of a storage battery, whilst the string itself was coupled to earth through a very high resistance

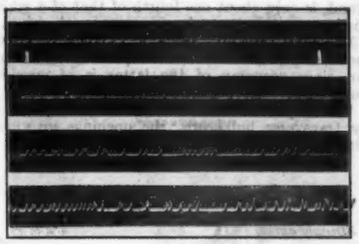


FIG. 24.

FIG. 25.

at one end and to the central wire of the detector vessel at the other. When an α particle entered the detector or counter the string was sharply deflected and continued displaced from its normal position until the conductivity of the air in the counter had disappeared. Dr. Geiger's final form of detector or counter is represented in Fig. 23. It consisted of a tube of about the size of a thimble, down the centre of which passed a finely pointed and highly polished needle, between which and the exterior of the vessel a potential difference of some 1,400 volts to 1,500 volts was established, which was nearly enough to produce a discharge. If an α particle entered by the small orifice shown to the left, it ionised the air inside, and these ions under the influence of the strong electric field produced a prodigious number of other ions, as already explained, thus enabling electricity to pass from the central needle to the wall of the vessel. The corresponding fall of potential was shown by a "kick" of the string of the electrometer, which was photographically recorded. Specimen records were reproduced in Fig. 24. Each "kick" was the result of the entrance of an α particle. It would be seen that the entrance of these was not regular, but was governed by the laws of chance, and occasionally two entered at practically the same instant. This counter, Sir Ernest said, would also record the emission of β rays. As the result of such experiments it had been proved that some $3{\cdot}6 \times 10^{10}$ α particles were emitted per second from a gramme of radium free from admixture with other radioactive materials. From a gramme of radium associated and in equilibrium with its descendants, four times this number of α particles were emitted per second.

There was another method of detecting the effect of single α particles. If the active deposit from radium were deposited on a fine needle point, then if in a dark room this plate were just touched with the point, and subsequently developed, the silver was reduced, and under a high magnifying power we got the effect shown in Fig. 25. In this the focus from which the particles were ejected was clearly marked, as was also their straight line passage through the film, each track representing the path of a single α particle.

THE GREAT EASTERN RAILWAY STEAMER "MALINES."

THE entry of the S.S. Malines into the Harwich-Antwerp service of the Great Eastern Railway Company, on the 21st inst., following on that of her sister ships the Antwerp and Bruges, built by Messrs. John Brown and Co., Limited, in 1920, and the opening of the new station offices at the Quai d'Herbouville, Antwerp, completes the programme of improved facilities for passenger traffic between England and Belgium decided upon by the company soon after the termination of the war. In respect of size, speed, accommodation and equipment the new ships are a considerable advance on the vessels, such as the Brussels, previously employed on this service, although these were very popular with the travelling public and were generally superior to the average class of vessel used for such short sea passages.

The Malines, which we propose to illustrate and describe in detail, was built at the Armstrong Yard of Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, at High Walker-on-Tyne. Her length is 337 ft. overall and 320 ft. between perpendiculars, while her other principal dimensions are:—Beam, 43 ft.; moulded depth to shelter deck, 26 ft. 6 in.; draught loaded, 15 ft.; and gross tonnage about 3,000. It will be convenient to defer our description of the passenger accommodation and public rooms to a subsequent issue, and to deal now with the machinery and boilers which were supplied and installed by the Wallsend Slipway and Engineering Company, Limited, of Wallsend-on-Tyne. The general arrangement of the machinery, which is of the single-reduction, geared-turbine type driving twin screws, is well shown in the longitudinal section and plan reproduced in Figs. 1 and 2, on Plate XVIII, accompanying this issue, while Figs. 3 to 5 are transverse sections through the boiler rooms and Figs. 6 to 10 are similar sections through the engine room. The half-tone engraving, Fig. 12, on page 394, is reproduced from a photograph of the turbines and gearing erected in the builders' shops.

The turbines are of the impulse type, and each set consists of separate high-pressure and low-pressure ahead units, working in series, with an astern turbine included in the same casing as the low-pressure ahead unit. In this type of turbine, impulse wheels are used for all stages of the expansion, and the grouping of the wheel stages is arranged so that the power production of both high-pressure and low-pressure units is approximately equal. The turbine casings are of cast-iron, as also are the diaphragms between the wheels, the nozzles in the diaphragms being formed of nickel steel plates cast in place. The rotor wheels and shafts have been made entirely from ingot steel forgings, and the blading is of phosphor bronze throughout. Adjusting blocks of the Michell type are fitted at the forward ends of each of the turbine shafts, and these, as well as the whole of the main bearings, are arranged to work under a system of forced lubrication. Rotating and fixed oil baffles are fitted on the rotor shafts between the glands and the bearings. Aspinall's governor gear is fitted to cut off the steam supply to the turbines in the event of a failure of the forced lubrication system and also if the speed should become excessive from any cause.

The torque of the turbines is transmitted to the pinions through couplings of the claw and sleeve type, made from forged material. The gearing is of the double helical type giving a 10·8 to 1 reduction, for the high-pressure turbine and 9·49 to 1 for the low-pressure turbine, the propeller shaft running at about 270 r.p.m. when developing full power. The pinions are of nickel steel, and the wheel rims upon which the teeth are cut, are made from ingot steel forgings, as also are the main shafts. For the lubrication of the gearing, oil sprayers are provided, and these are fitted so that the oil is delivered on to the teeth as they come into engagement. The bearings for the pinion and gear wheel shafts are also supplied with forced lubrication. The main thrust bearing is of the Michell type and its shaft, as well as the intermediate and propeller shafts, are made from ingot steel forgings. The propellers are of Stone's improved manganese bronze, 9 ft. 9 in.

diameter, with a pitch of 10 ft. 3 in. Vickers' glands are fitted to the aft end of the stern tubes.

The main condensers, which were constructed by the Wallsend Slipway and Engineering Company, are placed on each side of the ship as is most clearly shown in Fig. 8, on Plate XVIII. The plant has been designed so that with the turbine machinery working at full service power, a vacuum of about 28½ in. of mercury can be maintained with the barometer at 30 in., the sea water temperature being such as usually obtains in the North Sea. Centrifugal circulating pumps direct coupled to high-speed engines are placed aft of the condensers as shown in Fig. 2, which also shows the position of the air pumps; the latter are of the Weir "dual" type. Other auxiliaries include a Weir multiflow feed heater, a feed filter, Weir's direct-acting feed pumps, forced-lubrication pumps also by Weir's, sanitary and water service pumps by Carruthers, bilge and ballast pumps and fresh water pumps, all of which are shown in Figs. 1 and 2 and 6 to 10, on Plate XVIII. An auxiliary condenser with its own air and circulating pumps is also fitted, and there are two 100 kw. electric generating sets driven by direct-coupled high-speed engines by Messrs. Matthew Paul and Co., Limited. A set of secondary batteries is carried to maintain the supply of current for 6 hours in an emergency. It may here be mentioned that hand-operated travelling hoists are provided in the engine-room for handling the casings of the turbines and gearing when it is necessary to remove them for inspection purposes. Electrically-driven ventilating fans are mounted in the engine-room hatchways to ensure a good circulation of air.

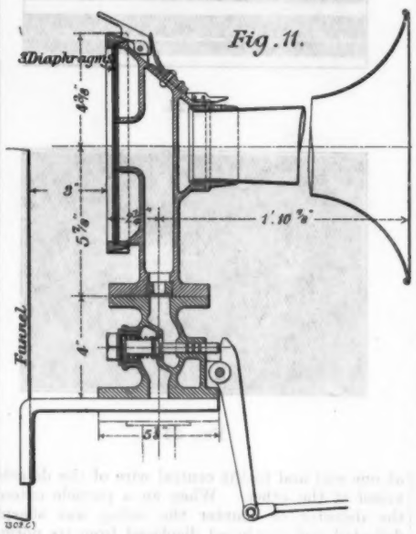
Steam is supplied by five main boilers of the ordinary return-tube type, arranged in two boiler rooms, as is best shown in the plan Fig. 2. Four of these boilers are placed back to back with a transverse bulkhead between them, and the fifth is placed aft in a recess in the cross bunker between the boiler-room and the engine-room. A donkey boiler, 7 ft. 6 in. in diameter and 7 ft. 6 in. long, also of the return tube type, is fitted in a similar recess in the forward cross-bunker in communication with the forward stokehold. The main boilers are single-ended, 16 ft. in diameter and 11 ft. 6 in. long, and each has four renewable corrugated furnaces with separate combustion chambers. The boilers are coal fired and are constructed for a working pressure of 200 lb. per square inch; there are no superheaters. The closed-stokehold system of forced draught is employed, air being supplied by four 80-in. fans, each driven by a 40-h.p. single-cylinder engine with forced lubrication, supplied by Messrs. Matthew Paul and Co., Limited. The fans are placed in a fan room on the main deck immediately over the boiler rooms, as shown in Figs. 1 and 3, the air being drawn through a trunk leading from an Allen's "cowless" ventilator on the boat deck. The two funnels are of circular section with outer casings carried up to the full height. In general it may be remarked that special attention has been given to the insulating of all hot surfaces by the application of non-conducting materials.

The steam mains leading to the engine-room are fitted with bends to take up expansion and give the necessary flexibility, the use of expansion joints being avoided in this way. Cockburn's manœuvring valves are mounted on the starting platform, which is situated in the forward part of the engine room and arranged so that all important machinery is visible from it. In addition to the usual gauges, counters, &c., a signal lamp and bell are provided to give immediate indication of any failure of the steering gear motor. The steering gear, it may be mentioned, is of the Brown electro-hydraulic type with telemotor control and hand gear combined. The engine and gearing for a Clarke-Chapman steam capstan are located in the steering compartment, the capstan itself, which is mounted on the shelter deck, being driven by a vertical shaft.

General cargo is carried in three holds forward and two aft of the engine-room, the cargo being handled by five Ayrolin combined winches and whipping gears. Arrangements are also made for the carriage of about 90 horses on the main and lower decks over the after holds. The method of bunkering these vessels is interesting. At Parkeston Quay the coal is delivered in trucks to a lift which raises them and tips the contents into a hopper. The latter feeds two belt conveyors, one of which runs along the quay to the berths for the Antwerp steamers, and the other to those for the vessels engaged in the Hook-of-Holland service. The belts deliver the coal into hoppers on the ship, shown in Figs. 4 and 5, and these hoppers are connected to the bunkers by steel-plate shoots. It is possible by this means to supply the necessary coal for a round voyage in about an hour, and by placing a canvas screen round the mouth of the hopper on the ship the dust is prevented from flying about.

A particularly complete equipment of navigating appliances is provided, including a Sperry gyroscopic compass, submarine sound-signalling apparatus, loud-speaking and intercommunication telephones, and a wireless telegraphy installation. The latter is provided with a specially-designed change-over switch which enables the wave-length to be altered instantaneously. We may here refer to a new form of whistle, or hooter, fitted on this vessel, in which the sound is produced by the vibration of metal diaphragms set in motion by steam. A sectional drawing of this device, which is known as the "Typhon" whistle, and is made by Messrs. J. Stone and Co., Limited, Deptford, is given in Fig. 11 annexed. The diaphragms are held in position in a conical casting by means of a screwed retaining ring fitted with a locking device to enable the tension to be adjusted. The diaphragms normally close the opening of the steam pipe, but when steam is turned on, the pressure is sufficient to move the diaphragms away from the opening so that some steam escapes and the pressure falls slightly. This allows the diaphragms to return and the pressure to rise again. The pressure fluctuations thus produced maintain the diaphragms in a continuous state of vibration which sets up sound waves in the surrounding air. The sound produced is of a very penetrating character, and the steam consumption, we understand, is only about one-fourth of that of a whistle of the organ-pipe type, having an equal range. The "Typhon" whistle is particularly suitable for use on motor ships, where it would be operated by compressed air, since economy of the latter is of considerable importance.

The ship is divided into watertight compartments by transverse bulkheads, the openings in which are fitted with Stone's hydraulically-operated doors. The



installation consists of 13 doors, two of which are situated between the shaft tunnel and the engine room, two between the stokehold and the engine room, and the remainder in the 'tween decks passenger accommodation; the latter, however, are arranged so that they are quite inconspicuous. The doors are, of course, operated in the usual way from the bridge, but they can also be opened or closed by a local control handle arranged so that when the latter is released after use, the door will return to the position indicated by the bridge control. The pumps for operating the watertight doors are indicated in Fig. 8. Six lifeboats, measuring 28 ft. by 8 ft. 6 in. by 3 ft. 6 in., are carried in Welin davits.

The full-power trials were carried out off the mouth of the Tyne on the 9th inst. and were highly satisfactory to all concerned. The vessel was required to steam at 21 knots for six hours with a deadweight of 170 tons on board, and to attain a speed of 21½ knots on the measured mile. Both conditions were easily complied with, although the state of the sea at the time of the trial was by no means favourable to the ship. The mean speed reached in the last two of four runs on the St. Abbs mile was 21·82 knots when developing a shaft horse power of 10665. The normal service speed of the vessel, it may be mentioned, is about 18 knots, but the additional speed is necessary to make up time when trains are delayed. Turning and astern running trials were also carried out, and the distance required for the vessel to come to rest from full speed ahead after giving the order to go full speed astern was also taken; this amounted to two lengths. The photograph reproduced in Fig. 13 on page 394 was taken during the course of the trials, and gives an excellent idea of the general appearance of the vessel; the straight stem should be noted, but the cruiser stern is best shown in Fig. 1 on Plate XVIII.

The machinery has been constructed throughout to comply with the requirements of the Board of Trade and with Lloyd's rules and regulations for passenger ships. Mr. F. W. Noal has acted as the owner's representative for the construction of the machinery.

(To be continued.)

FLOATING BUSHES FOR LOCOMOTIVE CONNECTING AND COUPLING RODS.

IN view of the discussion on American and British locomotive practice, which has just taken place at the Institution of Mechanical Engineers, part of which was reported in our last issue, while the remainder appears elsewhere in this, it will probably be of some interest to give a few particulars of the use in America of floating bushes in side and main rods. On the large engines in use in the United States a good deal of trouble has arisen from the heating of main crank and side rod pins. As piston thrust has increased the diameter of the main pin has been increased, but this has brought to the fore the question of rubbing speed.

About 1912 the experiment was tried on the Chesapeake and Ohio Railroad of introducing floating bushes on a heavy engine of the 4-8-2 type which had given a great deal of trouble from the main pins heating. The experience gained with this engine appears to have been favourable. The El Paso and South Western Railroad were the next road to take this subject up, which they did in 1915. According to Mr. T. Paxton, superintendent of motive power, El Paso, this type of bush was tried because of trouble from heating of big-end brasses. The frequent pulling down of the straps, knocking out of bolts, fitting, reaming, &c., were avoided by adopting loose circular bushes which could be turned in a lathe at a cost of about one-eighth the cost of making and fitting a pair of ordinary brasses, to say nothing of the great saving in time to engines.

The arrangement first tried on the El Paso road is illustrated in Figs. 1 to 3 opposite, details of the loose bush being given in Figs. 4 and 5. This design was merely an adaptation of the usual strap big-end which was replaced by a solid end fitted with straps, and bored to take a steel bush pressed in, within which was the brass floating bush. This design was applied on ten 4–6–2 type locomotives. It follows of necessity that if such loose bushes prove satisfactory there is no object whatever in retaining the expensive strap type of big-end, and the natural development from this more or less experimental design was the solid big-end as illustrated in our next Figs., 6 and 7.

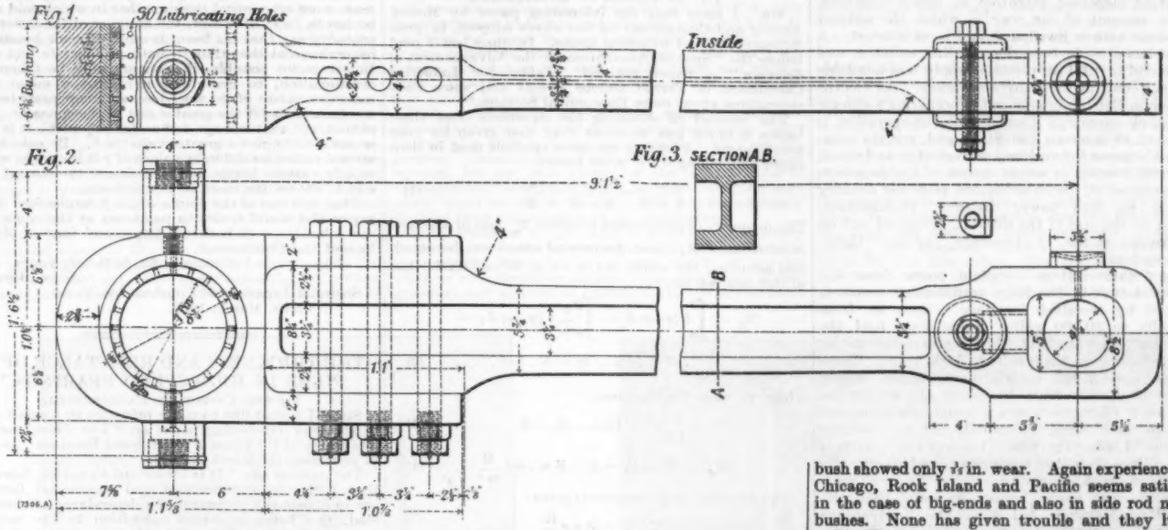
These illustrations show the main rods of heavy 2-8-2 type engines on this line. A similar design of bush had also been used in a lighter rod on a class of heavy 4-6-2 type engines sometime before. These designs embodied a solid big-end fitted with a steel bush pressed in, inside which was the floating brass bush.

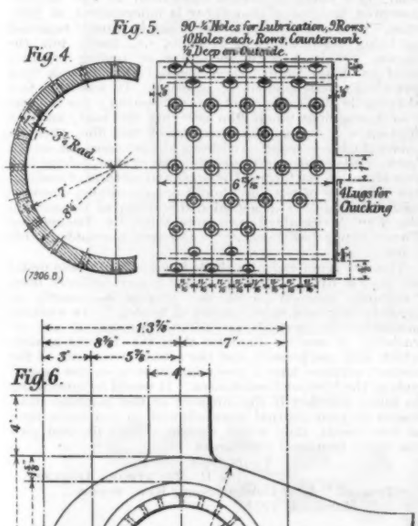
A particularly interesting application was made in the case of an engine to the United States Railroad Administration standard 2-8-2 design. Five such engines were delivered to the El Paso road in January, 1919, and one month later one broke a big-end strap through the brasses heating and breaking. Instead of renewing the brass a new big-end with a floating bush was fitted, and between March and December, 1919, ran 20,626 miles, when the bushing was renewed on account of wear. The engine was then sold to the Great Northern Railway, and the report from this line was to the effect that, after running 1,700 miles on the El Paso before leaving, it gave a further eight months wear on the Great Northern Railway. After a first attempt at renewal which seems to have given poor results, a better fit was made and satisfactory service obtained from the new bush applied.

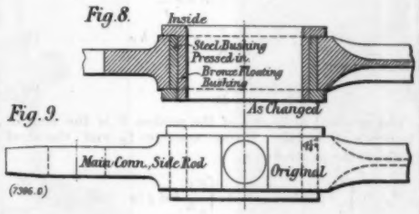
The application of floating bushes to side rods is illustrated in Figs. 8 to 13, these also being an example of practice on the El Paso road. The drawings are self-explanatory. Mr. Paxton states that in all these cases the Chesapeake and Ohio design was followed of using a bronze bush inside a fixed steel bush. He now considers the experience gained to warrant the elimination of the steel bush for new work, introducing the steel bush subsequently if necessary to make up for wear. The allowance provided between the brass and steel bushes on the El Paso is $\frac{1}{64}$ in. The bushes are perforated by a number of ¼ in. holes, and grease lubrication is employed. The temperature required to produce good lubrication with this system causes the brass bush to expand. This has to be allowed for in fitting. As regards life, Mr. Paxton reports that the heavy 4-6-2 type engines average 15,000 miles per bushing (for big-ends), while heavy 2-8-2 eingines give 12,000 miles. Bushes showing $\frac{3}{32}$ in. wear are renewed. In some cases this mileage has amounted to 60,000 for the first class and 40,000 for the second type of engine.

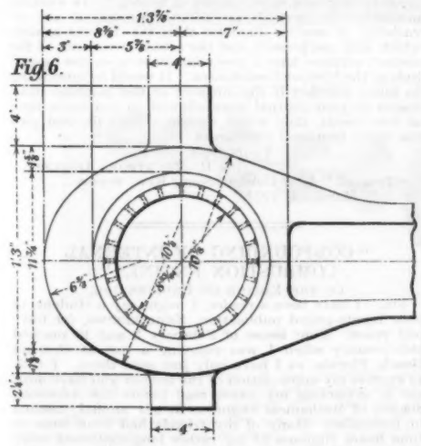
The life obtained varies a good deal. The Missouri Pacific Railroad, which has made more use of floating

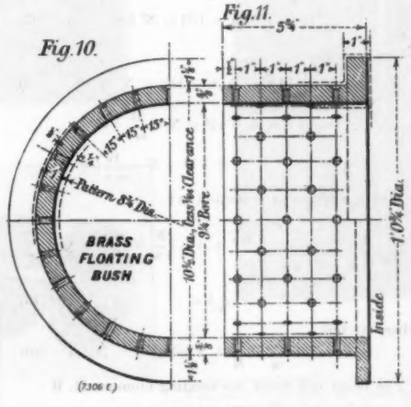
FLOATING BUSHES FOR LOCOMOTIVE CONNECTING AND COUPLING RODS.

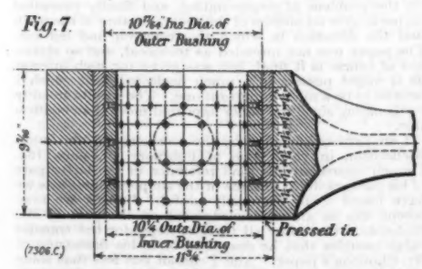


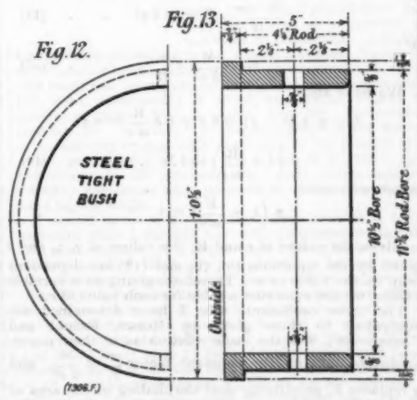












bushes on side rods, but has also main rods similarly equipped, get 30,000 miles to 35,000 miles out of main side rod floating bushes, compared with 5,000 miles to 7,000 miles for solid bushes on the same engines. This road reports that no trouble arises from lubrication or hot pins. On one engine fitted on one side with big-end brasses and on the other with a floating bush, the big-end had to be taken down three times to take up wear, and the brasses had to be renewed once while making 20,000 miles, during which the floating bush showed only ⅛ in. wear. Again experience on the Chicago, Rock Island and Pacific seems satisfactory in the case of big-ends and also in side rod main pin bushes. None has given trouble and they lubricate well. The experience of this road has not been long enough for the life to be safely determined. The Los Angeles and Salt Lake, and the Western Pacific are other roads on which the same principle has been applied, these lines having used floating bushes on all side rod pins in some engines. A point worthy of note is that replacement of a bush in the shed is a very simple matter. The floating bush can, of course, only be used in the case of big ends, on outside cylinder engines.

We are able to give the above information through the courtesy of Messrs. Davis and Lloyd, the London representative of the American Locomotive Sales Corporation, whose offices are at 26, Victoria-street, Westminster, the American Locomotive Company, which has built a good many of the engines fitted in this way, having kindly collected for us, from the roads concerned in America, the latest information on the behaviour of these bushes in practice.

MUNICIPAL MACHINERY.—The Institution of Municipal and County Engineers is arranging for comparative trials of selected classes of machinery, demonstrations of others and kinematograph exhibitions of such as cannot be actually shown in operation, the machinery being that used for the construction and maintenance of roads, refuse and sewage disposal, water supply, &c. The results will be given at the annual meeting at Cardiff next June.

UNIVERSITY COLLEGE, LONDON: ENTRANCE EXHIBITION.—We are informed that two open entrance exhibitions, tenable at the Bartlett School of Architecture, of the value of 40*l.* a year, may be awarded in June next by University College, London. Candidates for the first exhibition must have passed the matriculation examination of the London University or some other examination accepted in its stead. Candidates for the second exhibition must be graduates of a British University or some other University approved by the Selecting Committee. The exhibitions may be tenable for five years, subject to satisfactory progress. Full particulars may be obtained from the Secretary, University College, London, W.C. 1.

NEW TELEPHONE CABLE TO IRELAND.—Telephonic communication with Northern Ireland will be considerably improved within the next few days by a new submarine cable which has been laid by the telegraph ship Monarch. The landing places of the cable are at Port Mora, Scotland, and Port Patrick, Donaghdee, Ireland, and its length is approximately 22 nautical miles. Tests are now being carried out on the cable, and if they are satisfactory, the land lines will be joined up at once and two additional trunk circuits provided between Glasgow and Belfast. The new cable contains four copper wires, each weighing about 170 lb. per nautical mile. The wires are insulated by balata, weighing nearly 200 lb. per nautical mile. The four wires will provide two "physical" circuits. In addition, by the system known as superposing, a "phantom" circuit will be added when required. A "phantom" circuit is obtained by using two "physical" circuits for the transmission of speech currents, representing a third trunk channel, without interference with conversations carried on over the "physical" circuits. It is anticipated that the new cable will be found suitable for the provision of further independent trunk channels in the future, by the method of "high frequency carrier-wave" telephony.

RURAL ELECTRIFICATION IN SWEDEN.

THE question of the electrification of rural districts is attracting increased attention in many countries, and some account of the way in which the subject is being dealt with in Sweden should be of interest. A good deal has already been done in that country, and up to the end of 1921 an electric supply was available over 35 per cent. of the cultivated areas. An electrification committee is now engaged in preparing a scheme for the whole country. Considerable co-operation is being aimed at between the State and private companies and between the various hydro-electric and steam stations which exist, or are in course of development. For the purpose of the co-ordinated plan the country is divided up into power districts. Distribution, depending on the size of the district, is carried out on what is known as the "two-voltage" or the "three-voltage" system.

On the "three-voltage" system power from the generating station in the large transformer centre is transmitted by so-called "voltage" lines at from 10,000 volts to 20,000 volts. These lines feed the voltage transformer stations, which again distribute by "local" lines at from 1,500 volts to 3,000 volts. These local lines feed street transformers, which supply consumers at low voltage by what are known as "farm" lines. Large motors are sometimes connected direct to the local lines, but usually not to a voltage higher than 1,500. On the "two-voltage" system the main village lines feed transformers which directly supply consumers at low voltage. The "two-voltage" system is in some cases cheaper to instal than the "three-voltage" system, but it has the disadvantage that a considerably larger number of transformers have to be connected to 10,000 volt or 20,000 volt lines. This is not altogether desirable, and tells against the "two-voltage" system when a widely branched system of local lines has to be installed.

The disadvantages of the "two-voltage" system on the low-tension distribution side may to some extent be minimised by choosing a fairly high consumers' voltage and so increasing the economic area of supply from a high-tension step-down transformer. In some cases a consumer's voltage of 500 has been adopted. Motors are direct connected to the lines on this system, but consumer's step-down transformers are installed for lighting. This scheme, however, adds complication and reduces efficiency. As a result of comparative trials of 220 volts, 380 volts and 500 volts as the consumer's pressure, it has been decided that 500 volts is not to be recommended for farm work. Apart from the question of the small lighting transformers, the voltage has proved to mean 5 per cent. higher cost of overhead work and 5 to 10 per cent. higher maintenance costs than 380 volts. Consumers' installations are also proved to cost from 15 per cent. to 20 per cent. more. As between 380 volts and 220 volts, the former has proved to possess several advantages. The saving in distribution is from 15 to 20 per cent., while the construction costs and annual charges are only some 2 per cent. higher than those proposed by the lower voltage. The higher voltage of 380 also better facilitates development and extensions.

As against its advantages on the "two-voltage" system, 380 volts does not appear to offer advantages with the "three-voltage" system. The advantage in permitting a larger area of distribution at consumer's voltage become of less importance when the "local" intermediate voltage of the "three-voltage" system is available, and apparently 220 volts as a consumer's voltage is preferred. There has been some idea that 380 volts on consumer's mains was likely to lead to accident, but experience shows that there is little in this idea, and apparently in cases where "two-voltage" supply is installed it is proposed that 380 volts shall be made the standard consumer's voltage.

CHAIR OF ENGINEERING AT LEEDS UNIVERSITY.—The Chair of Civil and Mechanical Engineering in the University of Leeds will shortly be vacant owing to the resignation of Professor J. Goodman, who has held the chair since 1890. The university has appointed a committee to recommend a successor to Professor Goodman. The University Council have recorded their sense of the value of the long and devoted service which Professor Goodman has given to the Engineering Department of the University. Professor Goodman proposes to give his time to research, and the University Council have assigned to him accommodation for this purpose.

SOUTH-WEST MIDLANDS ELECTRICITY DISTRICT.—The Electricity Commissioners have provisionally determined the above district on the lines of the scheme submitted jointly by the Corporation of Birmingham and the Shropshire, Worcestershire and Staffordshire Electric Power Company, subject to minor modifications, which involve, among other matters, the exclusion of the Municipal Borough of Stourbridge and the inclusion of the Municipal Borough of Tamworth. The joint scheme of the Corporation and Power Company as amended during the course of the inquiry is approved generally. It is hoped that the further inquiry which is required by the Electricity Act of 1919, will be held in May.

"THE RAPID CALCULATION OF FERRO-CONCRETE BEAMS."

TO THE EDITOR OF ENGINEERING.

SIR,- -I have read the interesting paper by Messrs. Esnouf and Coutanceau on the above subject, in your February 10 and following issues. In June last I read before the "Spanish Association for the Advancement of Sciences" a paper entitled "Tables for Inductive Calculation of Ferro-Concrete Beams and some Considerations about more Economical Sections."

The method of obtaining the equations from these tables is much less laborious than that given by your contributors. Adopting the same symbols used in their paper and calling $n\,e = y$, we have:

$$\frac{y}{h-y} = \frac{n\,e}{h-y} = \frac{m\,r}{R} \quad . \quad . \quad (1)$$

The moments of compressed concrete M_c and of the steel reinforcement M_s about the neutral axis, must be equal, and assuming the width of the rib to be one-sixth that of the slab, we have:

$$M_c = \int_o^e b\,(y-\rho)\,d\,\rho + \int_e^y \frac{1}{6}\,b\,(y-\rho)\,d\,\rho =$$

$$\frac{b\,e^2}{12}\,(n^2 + 10\,n - 5) = N\,.\,b\,e^2 \quad . \quad . \quad (2)$$

where we write for shortness:

$$\frac{1}{12}\,(n^2 + 10\,n - 5) = N \quad . \quad . \quad (3)$$

$$M_s = S\,.\,m\,(h-y) = S\,m\,.\,n\,e\,\frac{R}{m\,r} \quad . \quad (4)$$

The equality of the moments gives:

$$N\,b\,e^2 = S\,n\,e\,\frac{R}{r}$$

$$\therefore S = \frac{N}{n}\,\frac{r}{R}\,b\,e = q\,.\,b\,e \quad . \quad . \quad (5)$$

where we put:

$$\frac{N}{n}\,.\,\frac{r}{R} = q \quad . \quad . \quad . \quad (6)$$

The moment of inertia of the section I is the sum of moments of inertia of the concrete I_c and the steel I_s about the neutral axis.

$$I_c = \int_o^e b\,d\,\rho\,(y-\rho)^2 + \int_e^y \frac{1}{6}\,b\,d\,\rho\,(y-\rho)^2 =$$

$$\frac{b\,e^3}{18}\,[6\,n^3 - 5\,(n-1)^3] = N'\,b\,e^3 \quad . \quad (7)$$

where we put:

$$\frac{1}{18}\,[6\,n^3 - 5\,(n-1)^3] = N' \quad . \quad . \quad (8)$$

$$I_s = S\,m\,(h-y)^2 = N\,n\,\frac{R}{m\,r}\,b\,e^3$$

$$I = I_c + I_s = N'\,b\,e^3 + N\,n\,\frac{R}{m\,r}\,b\,e^3$$

The modulus of the section is:

$$Z = \frac{I}{h-y} = \frac{N' + N\,n\,\dfrac{R}{m\,r}}{n\,e\,\dfrac{R}{m\,r}}\,b\,e^3 = \left(\frac{N'}{n} \times \frac{m\,r}{R} + N\right) b\,e^2 =$$

$$z_s\,b\,e^2 \quad . \quad . \quad . \quad . \quad (9)$$

where we put

$$\frac{N'}{n} \times \frac{m}{R} + N = z_s \quad . \quad . \quad . \quad (10)$$

The beam will resist the bending moment M, if:

$$\frac{M \times m}{R} = Z = z_s\,b\,e^2 \quad . \quad . \quad (11)$$

or:

$$z_s = \frac{M}{b\,e^2} \times \frac{m}{R} \quad . \quad . \quad . \quad (12)$$

We have also:

$$h = y + (h-y) = n\,e + n\,e\,\frac{R}{m\,r} = n\,e$$

$$\left(1 + \frac{R}{m\,r}\right) = i\,.\,e \quad . \quad . \quad . \quad (13)$$

where we write:

$$n\left(1 + \frac{R}{m\,r}\right) = i$$

Given the values of r and R, the values of q, z_s and i given by the equations (5), (9) and (13) are dependent only on the value of n. Therefore, giving to n variable values, we can construct a table for each value of r.

The three coefficients that I have determined are equivalent to those given by Messrs. Esnouf and Coutanceau: i is the same relation as in their paper, z_s differs only on the constant factor $\frac{m}{R}$ of $\frac{M}{b\,e^2}$, and q replaces k, permitting thus the finding of the area of steel reinforcement.

My coefficients are, however, dimensionless, and can therefore be employed either with the metric or English systems of units, supposing that M is expressed in pound-inches, b, e and h in inches and r and R in lb./in.^{2} The authors of the above paper state in a footnote that, taking economy into consideration, we must always, as far as possible, give to h a value greater than the minimum value found from Table I. In many instances experience has shown me that the cheapest beams are those in which r is between 430 and 500 lb./in.^{2} A section in which the concrete stress is 450 lb./in.^{2} may be 15 per cent. more economical than another in which said stress be 700 lb./in.^{2} However, the designer of the latter may probably say that his beam is more efficient because he has exhausted the strength both of concrete and steel. But it is not possible, if economy only be taken into consideration, to give to h too great a value. The reduction in cost of the steel does not compensate beyond a certain limit for the greater cost of the concrete. One cannot say that *always and as far as possible* it is more economical to give a greater value to h. By calculating several tables for different values of r it is easy to obtain rapidly various beams and to estimate the cost of each and to choose the more economical one.

That was one of the points which I emphasised in my paper, and would desire to point out at the same time the coincidence of both my paper and that of Messrs. Esnouf and Coutanceau.

I remain, Sir, faithfully yours,

JUAN BOTIN.

Sociedad Española de Construccion Naval,
Cadiz, March, 1922.

"THE THICKNESS AND RESISTANCE OF OIL FILMS IN HIGH-SPEED BEARINGS."

TO THE EDITOR OF ENGINEERING.

SIR,—I should like to make reference to a small point in the very interesting paper on "The Thickness and Resistance of Oil Films in High-Speed Bearings" printed in your issue for March 3, 1922.

The authors say "It is important to notice, however, that both the experimental and theoretical formulæ are in agreement respecting the dependance of shear on load, this being in direct opposition to the usually-accepted statement that shear is independent of pressure." I was not aware that shear is usually regarded as being independent of pressure, *i.e.*, load; but the results obtained with the form of testing machine used by Beauchamp Tower showed that it was then practically independent of pressure. It was this fact that made the experiments so interesting; for if there was a complete liquid film carrying the load, and the friction was due to the viscosity of this film, then its mean thickness must have been almost constant for all loads. Now Osborne Reynolds showed that, taking into consideration the form of the brass and method of loading, the thickness of the film should remain almost constant with all loads. The actual distribution of pressure in the film, ascertained experimentally by Beauchamp Tower, supported the study of Osborne Reynolds in this respect.

The two symmetrically-shaped bearings of white metal are stated by the authors of the paper to have been "carefully scraped to fit the journal as exactly as possible over an area of contact of 90 deg." In working machines the journals are almost always, if not invariably, of smaller diameter than the brasses against which they are pressed, and the actual curvatures of the contact surfaces have a great influence upon the magnitude of the frictional resistances. It would be interesting to know whether if the surfaces of the machine illustrated in your journal were allowed to run for a time at low speeds, they would remain a good fit, and give the same frictional resistances.

Yours truly,

R. MOUNTFORD DEELEY.

"Tintagil," Kew Gardens-road, Kew, Surrey.
March 24, 1922.

"COMPOUNDING OF INTERNAL COMBUSTION ENGINES."

TO THE EDITOR OF ENGINEERING.

SIR,—I have been a reader, I might say a student, of your highly-prized publication, ENGINEERING, for forty odd years. Your issues of February 3 and 10 reached this country when I was enjoying a rest at Ormond Beach, Florida, so I have only just seen them. I wish to express my appreciation of the honour you have done me in extracting my paper read before the American Society of Mechanical Engineers at our annual meeting in December. Many of my friends had from time to time heard rumours of my rather long-continued work on the problem of compounding, and finally prevailed on me to give an outline of the general nature of the work and the direction in which this research had led me. The paper was not intended as technical, and so states, nor of course is it final, but was given for such interest as it might possess in a much neglected field which I believe to be a most important one. The results steadily forthcoming since the paper appeared more than confirm this.

I am further honoured by the comments of Mr. James Richardson in your issue of February 10, page 164. I much appreciate his kind reference in the latter part of his paragraph (5) to some of the simple refinements we have found to be extremely useful. I think we may accept this as an acknowledgment on the part of Mr. Richardson that after all there is hope for the transfer valve troubles that he despaired of in his discussion of Mr. Chorlton's paper. And I cannot but feel that some of the other features will rise in his estimation when their true significance is realised. Mr. Richardson, I think, will grant that some of these may be quite new to him, whereas we have been struggling with them for many years.

Some others of the six headings under Mr. Richardson's "very careful analysis" might be touched upon as follows: With reference to (1), just the reverse of his

statement I feel to be true. The underlying requirement of successful compounding is the relatively very large combustion chamber yielding a volume of power gases sufficient to do work through two cylinders successively. This large size secures the condition necessary to efficiency in fuel burning with solid injection—the suppression of the great enemy to this economy, namely, the extensive chilled walls for each unit volume of the highly-compressed air at the instant of fuel injection. These chilled walls are only a fraction of those present in the normal Diesel. This insures still another advantage in freedom of range of cheap fuels available. The space being large and not cramped, it is possible to use many more nozzles and points of contact between the fuel and the compressed air, securing more complete combustion without the sprays impinging on the chilled walls. This ability to confine the spray impingement to the air itself at numerous points is also one of the contributory elements insuring detonation.

With reference to (2), the "combination" referred to is not sought. The detonation card mentioned in (3), with its extended expansion curve extending, as it does, through more than 300 deg. of the crank and with its lower exhaust temperatures, is the preferred form. This makes a definite contribution to economy over the constant pressure card. I do not know that we care so much whether it does, or does not, "necessarily follow from the pressure volume relations" as we do about its complete reliability in securing this high intensity form of combustion with its collateral effects in securing more complete combustion, evidently jarring or "shocking more molecules into union."

With reference to (4), I cannot agree that 30 lb. to the brake horse-power is not exceptional. Possibly Mr. Richardson can point out a few instances, especially considering that this applies to the ordinary run of engines, designed with no thought whatever of lightness nor introducing any refinements looking to this end. When these refinements are introduced, however, we find that compounding permits us still further quite remarkable gains in weight per brake horse-power. Fortunately we do not have to compare the compound with other than trunk engines to bring into strong contrast the gain in weight. We all know of many instances of these engines in service running between 150 lb. and 350 lb. to the brake horse-power, many of them running at much higher piston speed than the comparatively low piston speed of 735 ft. employed in our 7-in. engine. Employing the same class of refinements as used in submarine engines, the weight comes much below the 30 lb. per horse-power.

In the compound much larger power units can be made with trunk engines than is possible with simple engines, the controlling factor covering this point, as is well known, being the relation of combustion piston and the wrist-pin bearing diameters. This gain follows from the fact that a given combustion cylinder in the compound accommodates from four to five times the fuel with a corresponding gain in power for the size. Naturally the alternative of this is that with the compound we do not have to resort to crossheads until we reach four or five times the power of the simple engine per combustion cylinder at the same piston speed and revolutions. It is felt that these are definite and vital gains that cannot be neglected.

With reference to (5), I have already made my acknowledgments. When speaking of the transfer valve I think it a little awkward to combine it with the expression "exhaust gases," because they are in no sense rejected, but are held strictly on the job. Thanks to compounding, these gases cannot be considered "exhaust gases" until far later in the cycle, after they have actually doubled their contribution to the crankshaft.

With reference to (6), isn't it a fact that virtually these selfsame losses have always had to be considered in compounding steam? In the early history of this art all these were doubtless dragged forth with many others, groomed and arrayed in opposition to the unthinkable change from simple to compound. Not only have none of these features been found prohibitive, but they have been so minimised as not even to be serious. And this has been the procedure in the present instance. Naturally there has not been a moment in the three decades in which this work has been pursued that all of these losses have not been prominently in mind, and means sought to minimise them. For instance, can Mr. Richardson consider his "fourthly" in this paragraph in the nature of a discovery or especially applicable to the present case when, as a matter of fact, this is one of the basic considerations in all compounding? All compounds invariably encounter back pressure on the piston of their next higher stage.

I would agree with Mr. Richardson that it is to be regretted that I did not have the performance, say the fuel consumption, of a larger than 7-in. cylinder to base reports on when the paper was written. Larger engines are, however, usually better than smaller engines and certainly much better than minute engines in this regard. Mr. Richardson refers to the smallness of the 7-in. cylinder twice in his remarks, but let us examine the performance of this little engine. It has given 0·302 lb. and 0·305 lb. of 16 to 22 Baumé fuel per indicated horse-power in spite of the fact that it has all the imperfections of an experimental engine. This we do not hesitate to submit as being fairly good performance for this size machine. Entirely unnecessary wire drawing exists at two points in this engine, which was found to rise to larger proportions than was expected and has been eliminated in later designs. Other than this, the mechanical losses in this engine are extremely low, as referred to in the paper.

From many valued sources I have received words of commendation for the work. Among my critics there have also been, of course, some in the "die hard" class who profess to see no virtue whatever in compounding, everything about it being wrong. To these, is it possible to emphasise too strongly the facts above referred to—the fuel consumption per indicator-diagram unit? If the British thermal units are being excessively absorbed by the chilled walls or going astray in the many ways claimed, they most emphatically would never reach the indicator, this being, I feel, a more complete answer to the various points raised than is sometimes realised.

I have spoken of larger engines. Since the paper was written we have also gone far enough to know that really small—as low as 20 b.h.p.—heavy oil engines on this cycle will be successful. I am enclosing three photographs of a 20-h.p. engine. The one disassembled (Fig. 1) shows in the foreground, from left to right, the single exhaust valve for the four-cylinder effect which the compound delivers, the two transfer valves, the back one with the sleeve removed, and the fuel pump. The camshaft is in the foreground with the seats for the five cams. The low-pressure piston is inverted to show clearly the comparatively small ledge constituting the pump. The second photograph (Fig. 2) is an aft elevation of the engine on the test bed, and the third (Fig. 3) shows the camshaft with cams and pump-operating gear.

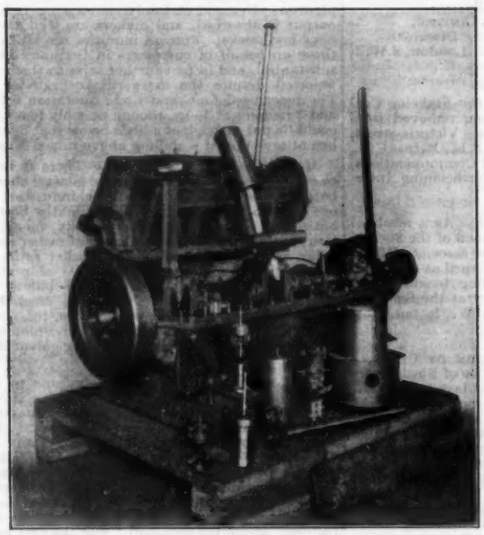


FIG. 1.

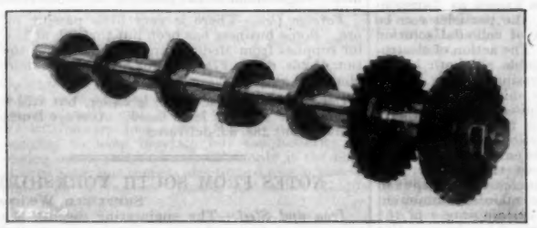


FIG. 3.

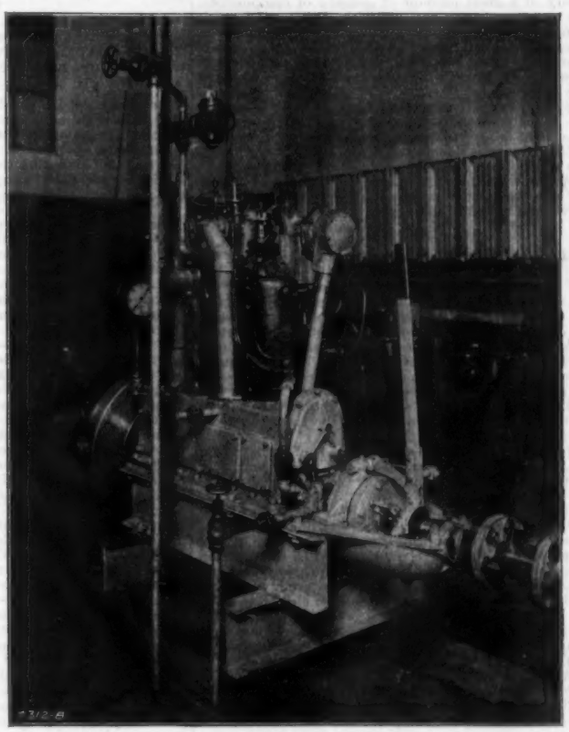


FIG. 2.

Respectfully,
EBENR. A. SPERRY, Dr. Eng.

The Sperry Gyroscope Company, Manhattan Bridge Plaza, Brooklyn, New York, March 9, 1922.

"THE PRODUCTION OF ACCURATE SCREW THREADS."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with interest Mr. A. A. Remington's letter in your issue of March 10 on the above subject. I do not think that any exception can be taken to anything he has said, and I would like to emphasise the necessity of a greater concentration on solving this most important tool-making problem.

To those who are familiar with the subject, the very great advance which has been made in Great Britain during the war has been very gratifying, and great credit is due to those engineers who helped to this achievement. Both the National Physical Laboratory and the British Engineering Standards Association have done pioneer work in surveying and standardisation, but the practical difficulty of thread production to meet the high standards which it is necessary to work to, is a problem worthy of the most strenuous effort of our best tool-makers.

One need only glance at a motor or aero engine to appreciate the need of better fitting screws. Every nut is suspect, and needs some locking device to ensure against its working loose. This liability to work loose would be lessened if screws and threaded holes were better fitting. I wonder how many lives have been sacrificed owing to a bad-fitting screw.

The "go" and "not go" ring and plug in any but a

gauge maker's hands is of very little value, and why this system has survived as long as it has done, on production, is because it was the best means available. The deficiency of this system is well understood by those who have studied the thread problem. The improvement of the art of thread gauging on production is a very great need, and every step towards the practical solution of the problem will be valuable to the engineer. By using five plugs to gauge a threaded hole a reasonable result is obtained, but even this number of gauges does not discover all the possible defects bearing on a good fit. In my own experience I have found that even seven plugs do not tell the whole story. The expense of gauges and inspection enter into the cost of the product, and a better and quicker method than plugs and rings is badly needed.

The advent of ground taps should go far to help towards this end, as the poor quality of commercial taps is responsible for a lot of bad work. It is pleasing to note that ground taps are now obtainable with a very close lead, the errors in pitch having been corrected by grinding.

By concentrating on the tap and chaser problem, to generate a better thread, would help to do away with the necessity of a great amount of gauging of components. Given an accurate tap to start with, and a good quick system of checking same, and some of our troubles would be greatly lessened. It is no use perfecting gauges if the commercial tap is to remain, as it is to produce bad work which the gauge will refuse; we have got to make better threads.

A loose pulley advertises itself by the noise it makes, and is quickly attended to, but a bad fitting screw is often a silent danger to human life, and is not discovered until the damage is done.

The projection system has focussed a strong light on the deplorable shams which have been called screws, and if we can keep this problem in the limelight some improvement is bound to follow.

Yours truly,
G. R. WILLIS.

44, Hartington-street, Derby, March 24, 1922.

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of March 10, Mr. A. A. Remington raises the old question of the gauging of screw threads, and I am sure the time is now ripe for such a discussion in order to prove the utter fallacy of using screw ring gauges and expecting the production to be interchangeable and at the same time a guaranteed "go" and "not go" limit to the effective diameter.

If there is a pitch error, all that is required to satisfy the screw ring gauge user is to make the threads thin in order to accommodate that error.

If the pitch is correct, but the threads of wrong form, all that is required is to make the major and core diameters slightly large, and again the screw ring gauge shows a good thread.

In our own case what brings this home far more forcibly is not the smaller sizes but anything above 2 in. diameter. When attempting to machine drive 3¼ in. diameter studs, Whitworth pitch, it will be readily seen that any error in effective diameter or in thread form will be fatal and probably mean that the stud will have to be drilled out owing to its tightness, or else be so slack as to be unfit for service. The only gauge that met this case with any degree of certainty was a new type of snap thread gauge which was recently described in ENGINEERING. Any error in form, core, major, or effective diameter is immediately shown, and the stud can be examined and can be guaranteed between whatever limits are desired with the same certainty that a round bar can be gauged.

Another purpose for which this new type of gauge was particularly useful was for checking large thread milling cutters. Any errors in manufacture of these cutters are very difficult to detect, and it is only after cutting a thread with the cutter and applying the snap gauge to the thread that any error could be detected. With this gauge the particular faulty thread could be instantly found and the cutter returned to the tool-room for rectification. When this method was applied, it was found that a large number of cutters which we had in the works were defective, and these defects were not even suspected when a screw ring gauge was used previous to the advent of the thread snap gauge.

This leaves another difficulty. If we are assured that by means of this gauge the male screw is right, we want some means of guaranteeing the tapped hole. This can only be done (commercially) by means of guaranteed taps, and, unfortunately, one very seldom comes across a tap that can be guaranteed.

It is high time that the tap makers of this country realise that they must sell their taps within certain limits of size. At present every maker has different ideas of how much to allow on a tap, and it is quite common when checking a tap of 3 in. or more in diameter to find it approximately 20 thousandths large. In order to overcome this difficulty, we had to insist that our tap makers supplied taps within certain limits set down by us. This the tap makers have agreed to, and the taps recently supplied have certainly been most satisfactory, but at extra cost. If the taps had been manufactured to a standard this extra cost would have been eliminated. It is absolutely necessary to have good taps in order to produce large units on more or less mass production methods. If tap makers would adopt a standard and guarantee their taps, it would make the duties of those responsible for the interchangeability of threaded items more pleasant, and also ensure a better product than has previously been turned out with a haphazard gauging with screw ring gauges.

Yours faithfully,
J. JAMIESON.

172, Lancefield-street, Glasgow, March 28, 1922.

"OIL FUEL BURNING."

TO THE EDITOR OF ENGINEERING.

SIR,—We were very much interested in Mr. J. J. Kermode's letter which appeared on page 370 of your issue of March 24, as for some years we have constructed boilers specially designed for burning fuel oil.

In many cases clients call for boilers which can be alternatively fired by coal or oil, in which case a compromise in design is necessitated, but as an example of the results obtainable on a boiler designed specially for fuel oil the following figures, taken from a test carried out on one of these units, by an independent authority, are interesting :—

Draught in inches of water ...	4 in.
Pounds of steam from and at 212 deg. F. per pound of oil without an economiser ...	17·1
Pounds of steam from and at 212 deg. F. per hour per square foot of heating surface	16·1
Thermal efficiency without economiser	89 per cent.
Combination	Smokeless.

Yours faithfully,
For SPENCER-BONECOURT, LIMITED,
P. ST. G. KIRKE, Director.

Parliament Mansions, Victoria-street, London, S.W. 1.
March 29, 1922.

PERSONAL.—The London office of the Staveley Coal and Iron Company, Limited, has been removed from Caxton House, Tothill-street, to 34, Victoria-street, Westminster.—Mr. C. P. Sandberg, C.B.E., M.Inst.C.E., has been appointed by the Ministry of Communications, Pekin, as technical delegate at the forthcoming International Railway Congress in Rome.

THE ROYAL AERONAUTICAL SOCIETY.—As a result of representations made to them, the Council of the Society has decided to hold the examination for associate fellowships in September next, instead of in April as originally arranged. The names of those wishing to sit in the examination should reach the secretary at the Society's Offices, 7, Albemarle-street, London, W. 1, not later than July 31.

THE PURIFICATION AND PREPARATION OF CLAYS.—A Technical Paper No. 281, on "The Use of Electrolytes in the Purification and Preparation of Clays," by H. G. Schurecht, ceramic chemist, has been published by the United States Bureau of Mines. As clays are of secondary origin, being derived from the decomposition and disintegration of the primary rocks, they differ in both physical and chemical constitution, depending upon the character of the original rocks and the conditions of deposition, says the author. Clays are not definite minerals, but they are made up largely of mineral fragments ranging in size from comparatively coarse grains to colloidal particles so fine that they can exhibit Brownian movements. Clays can be obtained so finely divided that they can make true colloidal solutions. Colloidal clay belongs to the class known as "suspensoids," and is reversible—that is, the particles can be dispersed in water or thrown out of colloidal solution by means of suitable electrolytes. The action of electrolytes has been an extremely valuable aid both in the purification of clay and in the casing of clay wares. Owing to changed conditions, due chiefly to the world war, many manufacturers in the United States have had to rely on domestic clays to take the place of those previously imported. Many domestic clays that are too impure to be used in the crude state can be utilised after purification. In order to improve the quality and uniformity of the product and to increase the output in purifying clays, it is necessary to maintain minimum viscosity in the clay slip during certain stages of the treatment. This minimum is governed by the quantity of alkalies added to the slip. The correct addition of alkalies to the casting slip is essential in the casting of clay wares. Heavy wares are not cast as extensively in America as in Europe. For instance, the casting of glass pots and other refractories is being carried on with success in many places in Europe, but it is practised only to a limited extent in America. One of the sources of loss in the manufacture of clay products, especially heavy wares such as chemical stone ware and glass pots, by the plastic and casting processes is lack of strength of clays in the dry state and at the firing temperature. Sufficient strength to resist the shocks and strains of handling in the green or dry state is necessary. At certain periods during the burning in the kiln the ware loses strength and is liable to warp, crack or break, causing heavy losses. The natural remedy would be to improve the strength of the clay body by artificial means or to introduce stronger clays. In preliminary work by the Bureau of Mines it was found that a surprising increase in strength was gained by adding alkalies to clay in the plastic state. In some instances the strength of the treated clays was four times as great as that of the untreated. Part of the investigation was limited to a study of the effects of different additions of alkalies and acids on the properties of clays with special reference to their influence on the strength. Many clays, which otherwise possess good properties, lack in plasticity and strength, and their use therefore is limited. In certain localities plastic clays of the fireclay type are comparatively scarce, whereas the non-plastic fireclays are abundant. Part of the purpose of the author's work was to determine how much the plasticity and strength of non-plastic clays could be increased by special treatment such as wet grinding, adding electrolytes, removing the coarse material by screening, and adding an organic binder such as dextrine.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Output of Cleveland pig-iron is very limited, and is likely to be even further curtailed by cessation of operations at two of the Tees Bridge Company's furnaces. Producers continue to complain that current rates are unremunerative, but a good deal of idle plant is ready for re-starting so soon as the time is considered opportune. Probably Messrs. Pease and Messrs. Cochrane will be among the first to rekindle furnaces. Continued high railway rates and labour troubles are the chief obstacles to expansion of output, but competition of other districts is also an important factor. Northamptonshire and Derbyshire irons are on sale at comparatively low figures, and conditions here are such that makers in this district are not likely to reduce their quotations which for home business and for export trade stand :—No. 1, and siliceous iron, 95*s.*; No. 3 G.M.B., 90*s.*; No. 4 foundry, 87*s.* 6*d.*; No. 4 forge, 82*s.* 6*d.*; and mottled and white, 80*s.*

Hematite.—As regards East Coast hematite, the position is decidedly better than is that of Cleveland pig-iron. Demand certainly shows some falling-off, but output is absorbed, and makers are well sold over the next few weeks. Foreign inquiries are still circulating, those on behalf of customers in Germany being rather substantial, and in fact further sales to that country are reported despite the extraordinary rate of exchange. The recognised f.o.t. and f.o.b. quotation for Nos. 1, 2 and 3 remains at 100*s.*, though possibly forward business could be put through at a little below that figure. No. 1. hematite is put at a shilling above mixed Nos.

Manufactured Iron and Steel.—There is little indeed to encourage hope of any material general change for the better in the finished iron and steel industries, though in one or two departments just a slightly better tone is noticeable. Manufacturers are ready enough to enter into contracts for shipment abroad at rather considerably below the following recognised market ratios for home purposes :—Common iron bars, 12*l.*; ship rivets, 14*l.*; steel billets (soft), 7*l.* 10*s.*; steel billets (medium), 8*l.* 15*s.*; steel billets (hard), 9*l.* 5*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 13*l.*; and corrugated galvanised sheets, 16*l.* 5*s.*

Ironworkers' Wages.—The accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England have this week certified the average net selling price of bars and angles for the two months ending February 28 last at 11*l.* 16*s.* 10·05*d.* per ton, as compared with 13*l.* 12*s.* 10·43*d.* per ton for the previous two months, and under sliding scale arrangements, puddlers and other forge and mill wages are reduced by 20 per cent. as from Monday last. This brings the men's rate of pay down to 47·5 (47½) per cent. above the standard. For the first two months of 1921 the average realised price of bars and angles was 26*l.* 19*s.* 7·97*d.*, and at the beginning of last year the men's wages stood at 230 per cent. above the standard.

Foreign Ore.—There is very little passing in foreign ore. Some business has been put through at 21*s.* to 22*s.* for supplies from Mediterannean sources, but the quotation of 26*s.* 6*d.* to 27*s.* c.i.f. for best rubio is more or less nominal.

Coke.—Blast-furnace coke is easier, but still too high to meet the views of local users. Average Durhams are round about 28*s.* 6*d.* delivered.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The engineering dispute is not the only serious factor that is militating against local progress. A deadlock has been reached in the steel ingot-making industry of Sheffield and Rotherham, with the result that the Amalgamated Engineering Union, the Electrical Trades Union, and the Associated Blacksmiths' Society have given notice to the firms in the Steel Ingot Makers' Association of their intention to withdraw labour from Saturday next. The cause of the dispute is the alleged action of steel ingot-making firms in placing semi-skilled members of these unions under sliding scale conditions applicable to labourers, thus, it is contended, reducing wages considerably below the district rate. Three large firms and approximately 1,000 operatives are principally concerned. The unions' action will result in the early paralysis of steel ingot production, at a time when output figures were beginning to make a little headway. Apart from these disputes there is little change in the general trade position. According to leading engineering masters there were signs of a creeping improvement and of more inquiries before the engineering trouble arose, but business now has received a general set-back on account of the indefinite outlook, and it is impossible to say that any substantial progress is being made at the moment towards actual recovery. Representative steel-makers declare that convincing signs of a revival may not be expected before September or October next, and that at least twelve months must elapse before normal conditions are restored. A satisfactory feature is the improved output of castings, indicating that there is still a certain amount of business being done in the shipbuilding trades. Engineering orders are few and far between. There is hope of big business being done with Roumanian State Railways if satisfactory conditions can be arranged as to payment and delivery, but considering the state of finances, local and national, the obstacle is a big one, and it will not come altogether as a surprise if Roumania takes advan-

tage of lower exchange rates operating in competitive countries. The new steel foundry of Messrs. Hadfield, Limited, which forms an important part of that company's adaptation of its war extensions to peace purposes, is now completed, and for some time has been working successfully. A large cogging and billeting mill also laid down by this firm is approaching completion. Very little business is passing in tool steels or tools of any description. Conditions in the market for raw and semi-finished materials are uneven. In some sections there are strong indications that rock-bottom prices have been reached. Soft basic billets, for instance, have this week been advanced 5*s.* to 7*l.* 15*s.* On the other hand, in order to meet increasingly severe competition from Northern producers, Siemens acid billets have been marked down to 10*l.*, at which figure they are alleged by local makers to be unremunerative.

South Yorkshire Coal Trade.—Inland consumption of steam hards begins seriously to reflect the effect of the engineering trouble. There is also a temporary lull in export buying, due, it is believed, to the expectation of lower rates. The operation of "daylight saving" has caused a further diminution in the consumption of gas fuels for domestic purposes. Prices of best quality slacks are maintained at the official level, but in lower grades bargains are to be had at remarkably low rates. Business in best quality house coal is on a rather larger scale, owing to weather conditions. Collieries have little difficulty in keeping clear of stocks. Quotations:—Best branch handpicked, 38*s.* to 39*s.*; Barnsley best Silkstone, 36*s.* to 37*s.*; Derbyshire best brights, 32*s.* to 34*s.*; Derbyshire best house coal, 32*s.* to 34*s.*; Derbyshire best large nuts, 28*s.* to 30*s.*; Derbyshire small nuts, 17*s.* to 19*s.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* 6*d.* to 22*s.* 6*d.*; rough slacks, 14*s.* to 15*s.*; nutty slacks, 8*s.* 6*d.* to 10*s.* 6*d.*; smalls, 2*s.* 6*d.* to 6*s.* 6*d.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

The State of Trade.—The state of trade generally throughout the country is not very satisfactory at the present time, and few industries can see very far ahead. The trouble in the engineering and shipbuilding trades is now having effect all round, and if the allied tradesmen are brought out in sympathy business will very quickly be disorganised. All classes of buyers are very disinclined to commit themselves, with the result that managements are faced with the prospect of closing down more plant in the near future unless things take a turn for the better very soon.

Scottish Steel Trade.—No improvement has taken place in the steel trade of Scotland, and the prevailing labour disputes have adversely affected the industry. Specifications for both ship plates and sections have fallen away considerably, and the prospects of an early revival are very poor indeed. This week very little fresh business has gone through and any orders are of small tonnage. Quietness is also very general in the black sheet trade, and the brighter outlook which had been noticeable is gradually fading away. Foreign business of all kinds is exceedingly slow, and little improvement can be looked for in that direction until the various exchanges abroad get on to a better footing. Prices show little change this week.

Malleable Iron Trade.—The West of Scotland malleable iron makers have not been booking much in the way of new business lately, and conditions at the works are not very satisfactory just now. A few establishments are managing to keep moving, but the majority are experiencing much broken time. Not only is the home demand very poor, but there is also little doing in Export. The home price of "crown" bars is still called 11*l.* 10*s.* per ton.

Scottish Pig-Iron Trade.—The conditions in the Scottish pig-iron trade are rather dull this week, as the demand, which was showing some signs of opening out, has again gone off. Buying is of a very hand-to-mouth character owing to the labour troubles, but if these were only settled it is generally anticipated that a gradual improvement might be forthcoming. Recent inquiries have certainly been more encouraging, but purchasers will not enter into large commitments pending a settlement of the disputes in the engineering and shipbuilding trades. The easier prices now ruling were expected to draw out orders, but so far little buying has resulted.

Wages in the Iron Trade.—Mr. John M. MacLeod, C.A., Glasgow, has made the following intimation to Messrs. James C. Bishop and Owen Coyle, joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board: "In terms of the remit, I have examined the employers' books for January and February, 1922, and I certify the average net selling price brought out is 12*l.* 15*s.* 6·92*d.* per ton." This means a decrease in the wages of the workmen of 15 per cent. on basis rates.

THE INSTITUTE OF METALS.—A ballot for the election of members and student-members of the Institute will be held at noon on Wednesday, April 19, in connection with the Twelfth Annual May Lecture. This lecture is to be delivered on Wednesday, May 3, by Professor Sir Ernest Rutherford, F.R.S., of Cambridge University, on "The Relation of the Elements." Membership application forms and cards of invitation to the lecture may be obtained on application to Mr. G. Shaw Scott, M.Sc., secretary of the Institute, 36, Victoria-street, London, S.W. 1. The subscriptions of persons elected on April 19, will cover membership to June 30, 1923.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—To-day, Friday, March 31, at 6 p.m. A paper by Mr. H. H. Jeffcott on "The Milling of Screws and other Problems in the Theory of Screw Threads," will be read and discussed.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 31, at 8 p.m., at Caxton Hall. Lecturette, "The Steel-melting Shop," by Mr. D. P. Dickinson (Member). Slides. Friday, April 7, at 8 p.m., at Caxton Hall. Lecturette, "Engineering in Southern Persia," by Mr. J. W. Maple (Member).

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Saturday, April 1, at 2.45 p.m., West Midland District Meeting at the Shirehall, Worcester. "Notes on the Arrangements and Working of a Highways Department Central Depot," by Mr. B. C. Hammond. Visit to Central Depot.

THE INSTITUTION OF BRITISH FOUNDEYMEN: LANCASHIRE BRANCH.—Saturday, April 1, at 4 p.m., in the College of Technology, Manchester, when Mr. C. Heggie, of Oldbury, Birmingham, will give a paper on "Plaster Patterns."

THE SOCIETY OF ENGINEERS.—Monday, April 3, at 5.30 p.m., in the Apartments of the Geological Society, Burlington House, Piccadilly, when a paper will be read on "Fractures in Concrete," by Mr. Harry Bentham.

THE BRADFORD ENGINEERING SOCIETY.—Monday, April 3, at 7.30 p.m., Lecture in the Hall of the Bradford Technical College, by Mr. J. Cauthery, on "Modern Water Tube Boiler Design," illustrated by lantern slides.

THE INSTITUTION OF CIVIL ENGINEERS: YORKSHIRE ASSOCIATION.—Monday, April 3, at 7.30 p.m., in the Hotel Metropole, Leeds, when a paper will be read by Mr. W. A. Burgess, entitled "The Application of Electricity to Modern Industrial Drives."

THE ROYAL SOCIETY OF ARTS.—Monday, April 3, at 8 p.m.: Cantor Lecture, "The Constituents of Essential Oils," by Mr. L. Guy Radcliffe, M.Sc.Tech., F.I.C., Lecturer in Applied Organic Chemistry, College of Technology, Manchester. (Lecture III.) Tuesday, April 4, at 4.30 p.m.: Dominions and Colonies Section, "New Zealand," by Lieutenant-Colonel Sir Thomas Bilbe Robinson, G.B.E., K.C.M.G. Colonel Hon. Sir James Allen, K.C.B., High Commissioner for New Zealand, will preside. Wednesday, April 5, at 8 p.m.: Ordinary Meeting. "Sea Encroachment and its Prevention," by Mr. Ernest R. Matthews, Assoc.M.Inst.C.E., F.R.S.E., of H.M.O.W., formerly Professor of Municipal Engineering, University of London. Lord Headley, M.Inst.C.E.I., will preside.

THE CLEVELAND INSTITUTION OF ENGINEERS.—Monday, April 3, in the Hall of the Cleveland Technical Institute, Corporation Road, Middlesbrough at 6.30 p.m., when a paper on "Open Hearth Furnaces and Auxiliary Plant," by Mr. A. V. Kemp, will be read and discussed.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 4, at 6 p.m. Paper to be read: "Corrosion of Ferrous Metals," by Sir Robert Abbott Hadfield, Bart. D.Sc., D.Met., F.R.S., M.Inst.C.E. And Ballot for New Members.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SOUTH MIDLAND CENTRE.—Tuesday, April 4, at 7.30 p.m., at the Grand Hotel, Colmore-row, Birmingham, a Conversazione will be held, and Mr. J. A. Cooper will deliver a lantern lecture entitled "With the Wireless Signal Company, R.E., in East Africa, 1916–18."

THE INSTITUTION OF NAVAL ARCHITECTS.—Wednesday, April 5, at 11 a.m., in the Lecture Hall of the Royal United Service Institution, Whitehall, S.W. 1: Address by the President (His Grace the Duke of Northumberland, C.B.E., M.V.O.); Sir Westcott Abell, K.B.E., M.Eng., on "Merchant Shipping and World Commerce in Relation to Sea Power"; Mr. J. H. Narbeth, C.B.E., M.V.O., on "Three Steps in Naval Construction—King Edward VII—Lord Nelson—Dreadnought." Afternoon meeting, at 3 p.m.: Mr. J. L. Kent, on "Resistance of Ships Among Waves." Thursday, April 6, at 11 a.m.: Dr. J. H. Smith, on "Nodal Arrangements of Geared Drives"; Mr. J. Wilkie, on "Double Reduction Gears in the S.S. Melmore Head"; Mr. T. C. Tobin, M.A., on "A Method of Determining the Natural Periods of Vibration of Ships." Afternoon Meeting, at 3 p.m.: Mr. John Reid, on "Possibilities of Fuel Economy in Marine Boilers"; Mr. J. L. Hodgson, on "The Metering of Steam." Evening Meeting, at 8 p.m.: Mr. James Richardson, B.Sc., on "Diesel Machinery for Single-Screw Motor Ships." Friday, April 7, Morning Meeting, at 11 a.m.: Mr. E. L. Champness, M.B.E., M.Sc., on "Longitudinal Strength of Cargo Vessels and its Variation with Fullness of Form"; Professor C. E. Inglis, M.A., on "Some Special Cases of Two-dimensional Stress or Strain"; Mr. John Tutin, on "The Economic Efficiency of Merchant Ships." Afternoon Meeting, at 3 p.m.: Mr. J. Rennie Barnett, O.B.E., on Recent developments in Motor Life-boats."

THE INSTITUTION OF ELECTRICAL ENGINEERS: WIRELESS SECTION MEETING.—Wednesday, April 5, at 6 p.m., "Provision of Power for Wireless Telegraphy," by Captain J. H. Whittaker-Swinton, R.E., Associate Member.

THE ASSOCIATION OF DROP FORGERS AND STAMPERS.—Wednesday, April 5, at 7.30 p.m., at the Chamber of Commerce, New-street, Birmingham, a Lecture will be delivered under the auspices of this association by Mr. Harry Brearley, on "The Making, Forging and Heat Treating of Nickel Chromium Steels."

THE INSTITUTION OF CIVIL ENGINEERS: BIRMINGHAM AND DISTRICT ASSOCIATION.—Thursday, April 6, at 6 p.m., at the University, Edmund-street, Birmingham, discussion on the Final Report of the Water Power Resources Committee.

THE OPTICAL SOCIETY.—Thursday, April 6, at 7.30 p.m., at the Imperial College of Science and Technology, South Kensington. The following papers will be presented and discussed: "Diffraction Halos in Normal and Glaucomatous Eyes," by Mr. H. H. Emsley, B.Sc., and E. F. Fincham; "The Effect of Changes of Curvature at the Focus of an Astronomical Object Glass," by Mr. E. Wilfred Taylor.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 6, at 6 p.m., Continued Discussion on Mr. R. Borlase Matthews' paper on "Applications of Electricity to Agriculture."

THE ROYAL AERONAUTICAL SOCIETY.—On Thursday, April 6, at 5.30 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C. 2, a paper entitled "Aerodynamical Efficiency and the Reduction of Air Transport Costs," will be read by Mr. Louis Bréguet.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 7, at 9 p.m., a discourse will be delivered by Sir Ernest Rutherford, LL.D., D.Sc., F.R.S., M.R.I., Professor of Natural Philosophy, R.I. The subject is "The Evolution of the Elements." Afternoon Lectures, at 3 p.m.: Tuesday, April 4, Mr. John W. Evans, D.Sc., F.R.S., M.R.I., on "Earth Movements" (Lecture II); Thursday, April 6, Mr. Arthur M. Hind, O.B.E., M.A., on "Landscape Etchers: New and Old" (Lecture II); Saturday, April 8, Sir Ernest Rutherford, LL.D., D.Sc., F.R.S., M.R.I., Professor of Natural Philosophy, R.I., on "Radio-activity" (Lecture VI).

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—Saturday, April 8, at 2.15 p.m., in the Royal Hotel, Barnsley. Paper, "Stainless Steel," by Dr. W. H. Hatfield, of the Brown-Firth Research Laboratories, Sheffield. The following will be open for discussion: "The Ignition of Firedamp," by Professor R. V. Wheeler, D.Sc.; "Memorandum on the Education of Colliery Officials in Yorkshire," prepared by the Joint Committee.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—No change of importance has taken place in the coal market during the past week. New business is quiet and the demand is less active than has been the case for some weeks past, but most collieries are comfortably stemmed and have full order books until the end of April, and consequently are not inclined to modify prices which remain on the basis of 27*s.* 6*d.* for best Admiralty large, 27*s.* second Admiralty large, and 26*s.* to 27*s.* for Monmouthshires, while smalls are from 19*s.* to 20*s.* for best steams, with other grades in proportion. Buyers, however, are anticipating the possibility of securing odd parcels at lower prices, counting on the non-arrival of expected shipping and congestion at the docks dislocating colliery arrangements, and causing them to require quick clearances of wagons. There was a further relapse in the volume of foreign export trade in the past week. Altogether 429,000 tons of coal were shipped to foreign countries as cargo which compared with 462,000 tons in the preceding week and 529,000 tons in the week ended March 10. Last week's total, however, was 179,000 tons in excess of the quantity dealt with in the corresponding week of a year ago, but 135,000 tons less than it was in 1913. Shipments from Cardiff last week totalled 294,000 tons, from Newport 73,000 tons, from Swansea and Port Talbot 29,000 tons each, and from Llanelly 3,700 tons. A considerable change again took place in the direction of such exports. Trade with Portugal showed a sharp recovery with a total of 25,000 tons, compared with only 1,395 tons in the preceding week and 26,000 tons a fortnight ago. Shipments to France amounted to 136,000 tons, to Italy 69,000 tons, South America 48,000 tons, Spain 36,000 tons, British coaling depots 24,000 tons, and other countries 90,000 tons. Negotiations which have been proceeding with a view to securing an adjustment of the working hours of coal trimmers and tippers at the South Wales ports have received a setback by the coal trimmers having decided to adhere to the present working hours, and refusing to sanction any change on the grounds that the present disorganised state of affairs and wastage of time at the dockside is due to the employers. It had been suggested that in place of the present system of working two continuous day shifts of 8 hours each two 9-hour shifts should be substituted, in which would be included a meal hour. This change, it was contended, would give the railway companies time to effect clearances at the tip sidings and also marshal wagons at the docks. The annual report of the United National Collieries, which has a capital of 1,578,020*l.*, has just been issued, and covers the year ended December 31, 1921. The profit for the year is shown at 133,451*l.*, or 104,000*l.* less than the profits realised in the previous year, while the dividend of 10 per cent. compares with 12½ per cent. a year ago.

THE CONCRETE INSTITUTE.—During the whole period of the Building Exhibition at Olympia, from Tuesday, April 11, until Thursday, April 27, the council have arranged for members of the Institute to have the use of a sitting room, which will be situate over the main entrance. A series of discussions has been arranged to be held in the small Conference Hall (over the main entrance) each day, from April 18 to 21, inclusive, commencing at 5.30 p.m.

THE GREAT EASTERN RAILWAY STEAMER "MALINES."

(*For Description, see Page* 387.)

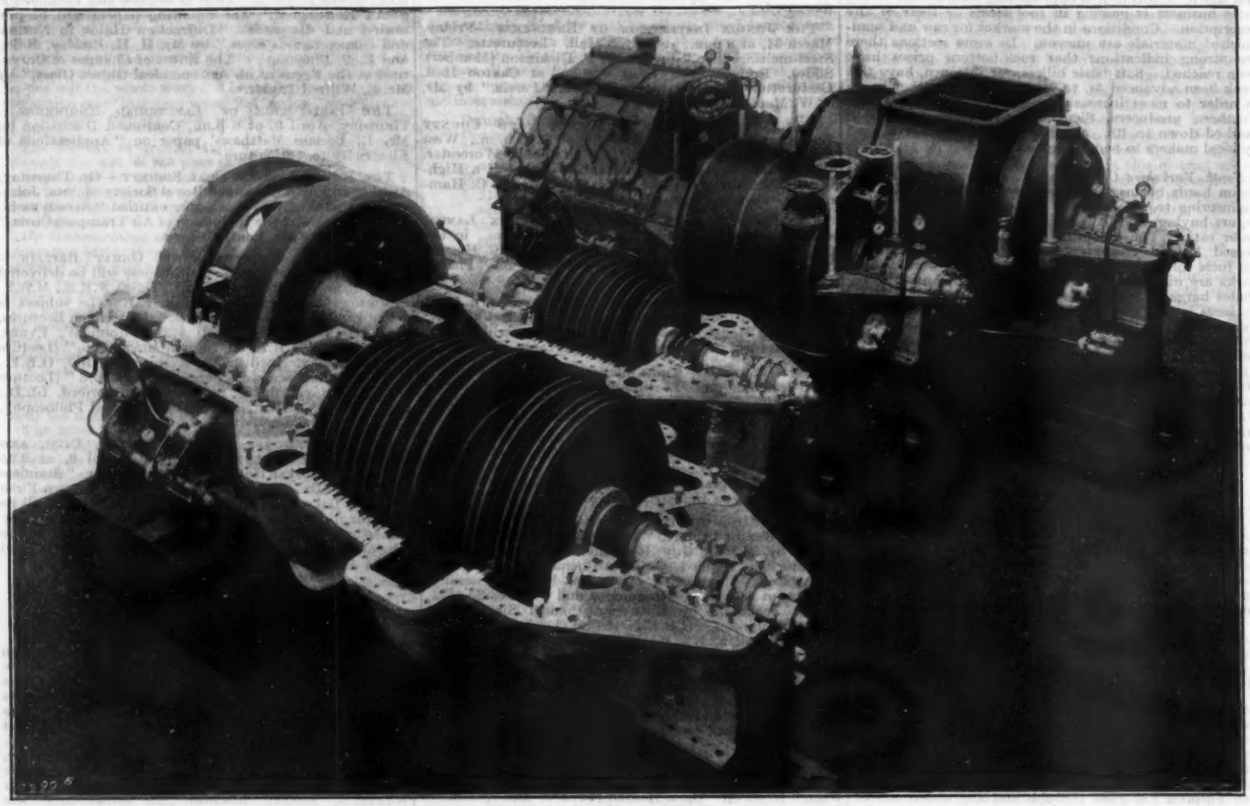


FIG. 12. THE TURBINES AND GEARING DURING ERECTION.

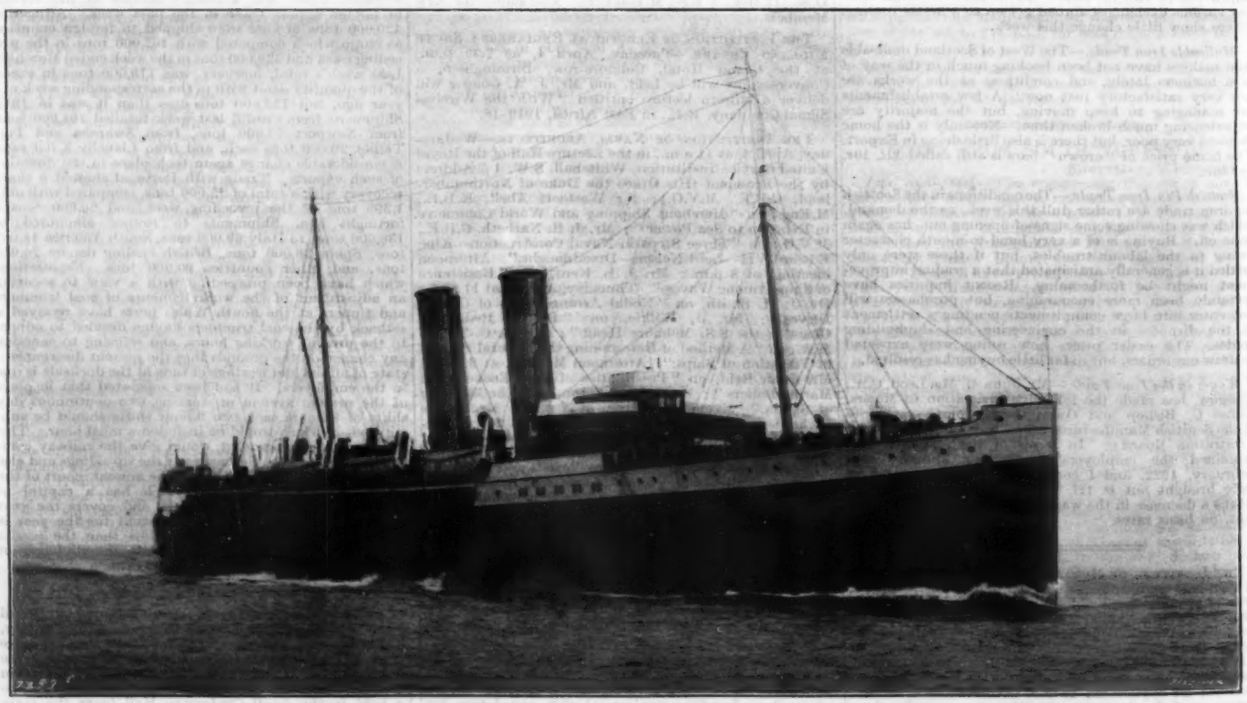


FIG. 13. THE VESSEL ON TRIAL.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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Two-Page Plate.—*MACHINERY AND BOILERS OF THE GREAT EASTERN RAILWAY STEAMER "MALINES."*

ENGINEERING.

FRIDAY, MARCH 31, 1922.

THE SIZE FACTOR IN STEAM TURBINES.

THE laws of similarity applicable to reciprocating engines have been frequently discussed. Thus it is well known that such engines geometrically similar and turning at corresponding speeds will have the same factor of safety, both as regards the stress due to the piston load and those arising from the inertia of the moving parts. An interesting application of this law was made by M. Normand many years ago, when he constructed the engines of the Russian ships Reavel and Sveaborg, as replicas of the engines of the Balny, to a scale 1·9 times greater. The general applicability of the rule has been further established by comparing the weights of similar engines. According to the law of similarity, whilst the output of engines run at corresponding speeds increases as the square of the scale, the weight increases as the cube and hence the weight per horse-power developed should increase directly as the cylinder diameter. That this rule is very approximately confirmed by practical experience was well shown by a diagram exhibited at a meeting of the Institution of Mechanical Engineers in 1912.

A corresponding law of similarity applies to steam turbines, but there is one distinction which is of some importance. In engine practice the deadweight carried by the shaft is commonly small compared with the load imposed by the steam pressures, or by the inertia of the moving parts, whilst in a turbine the bending stresses are entirely due to the weight of the rotor which increases as the cube of the scale. Hence with geometrically similar rotors the bending stress on the shaft will increase in direct proportion to the scale. As regards output, however, the same rule applies, as in the case of the reciprocating engine, viz., that at corresponding speeds the output increases as the square of the scale. The law of corresponding speeds is also the same as for reciprocators, viz., that the revolutions per minute must be inversely proportional to the relative scale. Thus if the mean diameter be doubled, the speed of rotation must be halved, thus keeping the blade speed constant. If this be done geometrically, similar wheels will have the same factor of safety against centrifugal stresses. Moreover, the factor of safety against "whipping" of the shaft will be proportionately the same, if the shafts be made geometrically similar. As already stated, however, the bending stresses due to the deadweight of the rotor would be higher in this case, and hence if the shafts be designed to have equal bending stresses the larger shaft will have a proportionately higher critical speed.

The effect of change of scale on the efficiency of geometrical similar turbines does not appear to have received much study as yet. The test data bearing on the matter, are scanty; but so far as they go appear to indicate that the effect of size on the efficiency is rather less than might have been anticipated. Unfortunately the evidence is much less direct than is desirable. A large turbine is not generally a replica of a small one to a larger scale, a condition of affairs for which commercial considerations are largely responsible. The cost of valves, governor gear, oil pumps, tachometers, gauges and other accessories forms a far greater proportion of the total cost of a small turbine than it does of a large one. Some interesting information on this head was given in a paper read before the Rugby Engineering Society in 1913, by Mr. J. P. Chittenden from which it appears that in the case of a turbine rated at 500 kw. the cost of accessories amounted to 45 per cent. of the total. With an output of 10,000 kw. this figure was reduced to 30 per cent. Hence small turbines have in general been constructed with a lower ratio of blade speed to steam speed than large ones, so as to keep down the cost per kilowatt of rated output.

For this reason the data for a direct determination of the effect of size on the efficiency hardly exist. In actual fact the published test data for small turbines and for large ones plot down very fairly on the same efficiency curve, but this constitutes by no means conclusive evidence that the effect of size on efficiency is unimportant, since for the reasons stated the large turbines and the small ones correspond to different regions of the curve and are not therefore similar turbines run at equivalent speeds.

That the test results do in general plot down with fair regularity is very satisfactory from the practical standpoint as it simplifies the work of the designer, but it is not what would have been anticipated from general considerations, almost all of which would lead us to anticipate that the element of mere size should have a by no means negligible influence on turbine efficiency. For example, from the theory of dimensions it appears that in geometrically-similar turbines run at corresponding speeds the waste of thermo-dynamic head in guide blade and bucket friction should vary as d^{-n}, where n is unknown, but is in all probability a small positive fraction, and d denotes some characteristic dimensions of the similar guide blades. In the actual practice of to-day, however, the dimensions of the guide blades and buckets hardly increases as fast as the diameter of the turbine, and this will tend to reduce the difference between the relative steam friction losses in large and in small machines.

The question of relative clearance losses is a difficult one. In general engineering work clearances vary rather as the square root of the scale than in direct proportion thereto, and if this rule held in steam turbine practice the larger the machine the smaller proportionately should be the losses by leakage. On the other hand, if the main proportions of the machine were strictly geometrically similar, the deflection of the shaft would increase directly as the scale and the limiting value of the clearances to which it is practicable to work must be a fraction of the shaft stiffness. If we attempt to obtain further light on this matter by a comparison with experience, we are again confronted with the lack of data which are fairly comparative, since in general the smaller machine will have fewer stages, and thus be relatively shorter than the large one, and the stiffness of shaft increases very rapidly as its length is reduced.

In the matter of waste of energy in disc friction and fan action, the actual losses in similar turbines run at corresponding speeds, vary rather less rapidly than the square of the diameter so far as disc

friction is concerned, and rather more rapidly than the square of the dimensions so far as fan action is involved. Since the output is proportional to the square of the dimensions, it is probable that rotation losses generally are proportionately not very different in similar machines.

In a paper by Mr. Eskel Berg, read before the American Institute of Electrical Engineers, in 1919, the total rotation losses in a turbine developing 21,000 h.p., running at 1,800 r.p.m., are given as only 1 per cent., but it has to be observed that the mean diameter of the first stage of this large turbine was 35 in. only, although the last stage was 88 in. in diameter. It would generally be commercially impracticable to make a small machine a replica of this to a smaller scale. A very usual practice is to make all stages of the same mean diameter, and the rotation losses then considerably exceed Mr. Berg's figure, being quite frequently between 2 per cent. and 3 per cent. of the total output.

Bearing losses from in general but an insignificant fraction of the total, absorbing in general well under 1 per cent. of the total output, so that their inclusion hardly affects the relative efficiency of large and small machines. Nevertheless the large machine has the advantage since the theory of lubrication leads to the apparently paradoxical conclusion in that with similar bearings run under similar conditions, the total friction loss would be identically the same on a large and on a small bearing. In practice similarity of conditions is never attained, since this would imply that the thickness of the oil film was reduced in the same proportion as the journal diameter, and that the latter carried the same load per inch of length irrespective of the scale. Actually a smaller bearing is far more lightly loaded per inch run than a large one. The oil film is therefore not geometrically similar in the two cases, and the loss in the smaller bearing is correspondingly diminished, whilst remaining, however, proportionately larger the smaller the scale. In any case, as already observed, the bearing losses are so small in modern turbine practice, that they hardly affect the comparison between similar units.

The trend of design for some considerable time past has been in favour of the largest possible units consistent with safety against centrifugal stresses. As much as 15,000 kw. is now being developed from a single-flow reaction turbine running at 3,000 r.p.m. The production of such a unit has naturally necessitated very striking departures from standard practice and the adoption of blade speeds and steam speeds far in excess of the limits usual hitherto. For the same rate of rotation Mr. J. B. Johnson, of the Westinghouse Company, has given the limiting size for a double-flow reaction machine as 10,000 kw., steam being supplied at a pressure of 250 lb. per square inch, and exhausted into a 29-in. vacuum.

High steam speeds, though conducive to a reduction of frictional losses, are, however, necessarily accompanied by larger "leaving" losses, and with modern high-speed machines the designer considers himself fortunate if he can reduce these to 3 per cent. of the total thermodynamic head. An hydraulic engineer would have been horrified at so large a sacrifice of kinetic energy; and indeed, in the earlier days of steam turbine practice, the "throw away" to exhaust seldom involved a loss of more than 2 per cent. In addition to large "leaving" losses the adoption of high steam speeds implies a reduction in the number of stages, and this involves some small diminution in the reheat factor, and in the effective thermodynamic head. Hence with a stated rate of revolution, the relative efficiency of a turbine with low steam speeds and with high steam speeds will not differ much, since what the one gains by lower frictional wastes, it loses by an increase in the throwaway losses and by a diminution in the reheat factor. This conclusion appears to be in accord with experience, so far as this is embodied in the published test data.

THE HALF-WATT LAMP PATENT.

IT is now generally known that the patent covering half-watt lamps has been upheld by the House of Lords. The judgments have just been published in the reports of patent, &c., cases, and contain information valuable to inventors, to all interested in patents and to those concerned with the manufacture of electric lamps. This patent was tested in the First Court and in the Court of Appeal, and every judge there gave judgment against the plaintiffs. In the final Appeal to the House of Lords every judge gave judgment in favour of the plaintiffs. This, therefore, in the first place shows how difficult it is for an everyday inventor to uphold his rights, to know what his rights are, or, what is more important for the public to know, what they may, or may not, do with respect to a patented process or device.

The patent in question deals with what were called half-watt lamps, but which for some reason not apparent are now referred to in the trade as gas-filled lamps, although the patent points out that it discloses how to make a lamp with a commercial life to run at an efficiency even as high as 0·4 of a watt per candle. The plaintiffs leading counsel in the House of Lords was reported to have said that the old tungsten lamp took about 1¼ watts per candle, the plaintiffs' lamp taking half-watt, or even less.

The main claim was for an incandescent electric lamp having a filament of tungsten or other refractory metal of large diameter or cross-section or of concentrated form, and a gas or vapour of low heat conductivity at relatively high pressure, the combination being such that the filament may be raised to a much higher temperature than is practicable in a vacuum lamp without prohibitive vaporisation or deterioration, or excessive shortening of useful life, all substantially as described in the specification.

In this latter document it was pointed out that the light emission of a lamp is in proportion to the eleventh power of the absolute temperature, so that a very slight increase of temperature above that normally used in incandescent lamps brings about a very considerable increase in efficiency. Further, it was discovered that within moderate limits loss of energy by conduction and convection is approximately independent of the size of the filament, so that there is very little difference in the magnitude of the conduction and convection losses as between a filament 10 mils. in diameter and a filament 3 mils. in diameter. The surface areas of the two filaments being in the ratio of 10 to 3 and the light emission at a given temperature being proportional to the surface, the 10-mil. filament will radiate more than three times as much light as the 3-mil. filament. It is this fact according to the patentees in conjunction with the reduced vaporisation obtained by a suitable choice of filament and atmosphere together with the other features described, which enables the efficiency above indicated to be secured.

Lord Haldane, in his judgment, pointed out that it was no mere abstract principle that had been discovered, but a process to embody a newly-discovered principle, namely, the principle that if use is made of an inert gas to restrict vaporisation the increase in loss of energy caused by conduction and convection will be less in proportion than the increase of light to be obtained. Scientists will agree that the discovery of such a principle and its application ought to be rewarded, but the difficulty in the case was rather whether toll should be taken from manufacturers of half-watt lamps on the basis of the specification as it stood in view of the allegation that the ambit of the claim was not so fairly explained that the public could know what they might do and what they were debarred by law from doing during the existence of the monopoly. The House of Lords have now held that the specification is sufficiently explicit as a whole in this respect.

There is one point that deserves emphasis in the Lord Chancellor's judgment, namely, that the specification is to be scanned with the closeness which is required in the case of any instrument conferring a monopoly, but subject to this all one can legitimately do is to apply the ordinary rules for the construction of written instruments. This is a timely re-statement of the law for inventors at the present time often consider that specifications should be more generously construed than their apparent construction warrants. If inventors have to be protected, so have the public, for every patent if valid, as the Lord Chancellor pointed out, restricts the liberty of other inventors and confers a monopoly. It is indeed right that such a monopoly be conferred provided the inventor on his part explains what is the monopoly claimed, and how the invention can be carried into effect by the public on the expiry of the monopoly.

In the particular case in question a good deal of difficulty arose in connection with the word "large" in respect to the size of a filament. It was suggested that there was no standard of comparison, and the patentees were not willing to limit their filaments to any particular range, as for example, between the 3 mils. and 10 mils. referred to above. On this point a passage in the judgment of Viscount Cave may be noted by inventors, namely, that it may be in selecting the filament in a particular case the lamp-maker will have to use his knowledge and skill, and he may require the aid of such calculations and workshop tests as are common in an industry of this nature. This is a re-statement of the law on the experiments which may need to be made by the public, but which do not vitiate the patent.

THE SURVEY OF PASSENGER STEAMERS.

MODIFICATIONS of the instructions issued by the Board of Trade for the survey of passenger steamships and passenger accommodation are not as a rule of great general interest and do not involve any radical departure from long established practice. In the new edition of these instructions just issued one or two modifications appear, which, while not involving any radical departure from previous practice are of interest as showing the growing importance of vessels driven by internal-combustion engines, and also for the definite adoption of new rules regarding bilge pumping arrangements based on the recommendations of the Bulkhead Committee. The general effect of these latter is to substitute power-driven pumps for the old hand lever type—these latter being considered useless except for pumping peaks, chain lockers, or other similar small spaces. Particular attention is directed toward maintaining the efficiency of the remaining bilge pumping system and preventing flooding of other compartments in the event of the vessel sustaining damage to a compartment involving the breaking of the bilge suction pipe from that compartment. Motor vessels are to be treated for bilge pumping purposes on the same basis as steam vessels of the same size and power and similarly employed. The effect of the modifications made in the pumping regulations will be to minimise considerably the risk of sinking in the case of a vessel which has sustained damage to such an extent that her bilge suction pipes are severed, and the open ends are in communication with the sea, for it has been established beyond doubt that vessels have been lost through the flooding of compartments other than the damaged one owing to the inflow of water through broken suction pipes.

Regulations governing the granting of special passenger certificates to small motor vessels have been substituted for those dealing only with motor launches and vessels carrying more than 36 passengers are included in this section. In the main the new rules in this section define the details and safeguards for propelling machinery, the stowage of fuel oil on board and the safeguards against the outbreak of fire on board. No modifications of good practice of the present time are involved, and none of the new regulations are likely to bear hardly on the development of this class of vessel.

The regulations as to testing of material have been revised and extended to include a few items such as turbine gearing, steel castings for patent davits, welded steel or iron pipes, but in this case also no alteration involving a new principle has been made.

The instructions as to the survey of passenger accommodation have been slightly modified, and now contain instructions relating to the carriage, on coasting voyages only, of fourth-class passengers on foreign-going vessels. Regulations as to the number of passengers to be carried in small steam or motor vessels on short excursions are incorporated, and the issue of a new class of passenger certificate—St. 6—for this type of vessel is

authorised. This latter regulation will hardly meet with the unqualified approval of the owners of small daylight excursion vessels, but in view of the serious overcrowding which took place at certain seasons of the year in the past the new regulations are to be commended. On the whole the new regulations do not bear harshly on shipowners, and the general effect of them will be to increase the safety of the vessels to which they apply.

NOTES.

THE CENTENARY OF NAVAL ENGINEERING.

IN a paper read before the Newcomen Society last night Eng.-Commander Edgar C. Smith, O.B.E., traced the development of the marine engine in the Navy from the launch of the Comet on May 11, 1822, up to the abandonment of the paddle engine, largely as the result of the experience gained in the Crimean War. The innovation was by no means welcome to the higher command in the Navy, just as the late Lord Beresford denounced the introduction of the Dreadnought, so did the Board of Admiralty in 1828 state that they "felt it their bounden duty on national and professional grounds to discourage, to the utmost of their ability the employment of steam vessels." Fortunately or unfortunately the refusal of one nation to encourage creative thought does not ensure that other nations will adopt a similar policy, and the use of armed steam ships off the African coast by the French in 1830 compelled "my Lords" to follow suit, although more than one admiral declared that "since the introduction of steam he had never seen a clean deck or a captain who, when he waited on him, did not look like a sweep." Sir Thomas Hardy (Nelson's Hardy), however, had greater prescience, and but a week before he died remarked, "That some people laugh at science, but science will alter the whole character of the Navy, depend upon it steam and gunnery are in their infancy." When at length the necessity of steam became too obvious to be ignored, the Admiralty effected a compromise. One idea which found favour was that every strong ship should have an attendant steamer, and this plan was followed for many years on the North American station, where in calms and light head winds the flagship was towed by her attendant steamer, which in its turn was towed by the flagship when the wind was favourable. The first engineers in the Navy had no special standing and were free to come and go much as they liked. Later on they were constituted warrant officers, ranking after gunners, boatswains and carpenters, but a dearth of recruits was experienced, and in 1847 their status was greatly improved, the corps being organised in seven grades, ranking with, but after, the masters, which then provided the navigating branch of the Navy. Commander Smith gave in his paper a comprehensive list of the old paddle-driven warships. From this it appears that the largest built was the Terrible, launched in 1847. This vessel measured 1,847 tons b.o.m., and was fitted by Maudsley with twin cylinder engines developing 2,059 i.h.p. The cylinders were 72 in. in diameter by 8 ft. stroke, and made 14 r.p.m. Very low pressures were used with the early engines, as boilermaking was still a somewhat primitive art. In testing them a liberal supply of bran was put in to check the leakage, and "weeps" of moderate strength were ignored as unimportant.

COMPRESSED GAS CYLINDERS.

The compressed gas industry in this country has been carried on in a very able way and accidents, either during the manufacture, or use, of compressed gases are almost unknown. This happy state of affairs has not been attained by mere chance, and very great credit is due to the compressed gas companies and others concerned. It will be remembered that a Gas Cylinders Research Committee was appointed in 1918 and that it has recently reported recommending the use of cylinders of slightly lighter section than those called for by the earlier official specification of 1895. This committee owed its existence to the large employment of gas cylinders by various government departments during the war, and was in no way called for by the representatives of a successful and very carefully-conducted industry. At the end of the war enormous stocks of gas cylinders of one kind and another were in the hands of some of the Government departments, and a very definite effort was made in certain quarters to introduce some of these cylinders into ordinary commerce. We do not know quite to what extent these efforts have been successful, but it is certain that many cylinders are now in circulation which do not comply with the specifications of either 1895 or 1921. Many obsolete war cylinders were sold at practically scrap value, while many cylinders of German origin recovered from submarines and other sources also passed into circulation. We understand that the responsible compressed gas companies refuse to charge these inferior cylinders, but that the whole situation is unsatisfactory and carries elements of danger is illustrated by the fact that the Home Office found it necessary a few days ago to issue a general warning and recommendation that purchasers of compressed gas should obtain certificates from the suppliers that all cylinders are manufactured, tested and filled in accordance with one or other of the official specifications. That the matter is one of definite moment was sufficiently illustrated, even to those having no special knowledge of the trade, by the serious explosion of a gas cylinder which occurred at Newcastle-on-Tyne last week and did very extensive damage. We understand this was a large cylinder from a German submarine, and that it contained hydrogen. The main trade in compressed gas is, of course, concerned with oxygen, and users who are in any doubt about cylinders in their possession may readily detect those which are lighter than specification by weighing them. Some useful figures bearing on this point have been made available by the British Oxygen Company. Cylinders containing 100 cub. ft. of oxygen and fitted with valves should weigh not less than 104 lb. full and 95 lb. empty. If fitted with foot rings and valve protecting caps, 13 lb. should be added to the above weights. Cylinders with valves and containing 150 cub. ft. of oxygen should weigh not less than 144 lb. full and 130 lb. empty, and 15 lb. should be added for foot rings and valve protecting caps. We trust that all users of gas cylinders which have not been supplied by firms of known reputation or which have not been subjected to regular inspection and testing, will bear these facts in mind.

STANDARDISATION.

Standardisation is a good servant but an extremely bad master. Premature efforts in this direction are most disastrous, as repeated experiences have proved; but when duly subordinated to more vital considerations, standardisation has played a predominant part in the reduction of manufacturing costs. Some highly interesting examples of this were given in a paper read last night before the North East Coast Institution of Engineers and Shipbuilders by Mr. C. le Maistre, C.B.E., the secretary to the British Engineering Standards Committee. He quoted Mr. H. J. Skelton to the effect that the savings effected in the production of rolled sections, had reduced the costs of production by 1,000,000*l.* per annum. So far back as 1914, 95 per cent. of the sections rolled at the five largest steel works in the kingdom were British standard sections. The tramway rail sections have been reduced from 75 to 5, and in the case of Portland cement practically the whole of our output is made to the standard specification. The organisation of the Committee is peculiarly British in character. In most other countries practically the whole expense would have been borne by the Treasury and the work done in the main by officials. Here, although the general funds receive grants from our Government and from the Overseas Dominions and from India, the chief burden is borne voluntarily by our industries. The charge, however, would appear to be really an investment rather than a mere subvention. During the past year no less than 40,000 copies of the standard specifications have been sold and arrangements are being made for their dissemination outside the Empire. To this end local committees have been formed in the great trading centres of the world, who act as advisers to the Home committee, and promote the use of these standards in the countries concerned. As matters now stand there are 385 committees, sub-committees and panels engaged in the work of instituting or amending standards. Included amongst the members are representatives of every interest concerned from producer to purchaser. Mr. C. le Maistre suggested in his paper that where standards recommended by the committees would involve the scrapping of existing stocks, these recommendations should temporarily be regarded as "recommended practice" not necessarily involving immediate compliance. In this way the change over might be made with a minimum disturbance to industry. There are also cases in which equally competent engineers hold irreconcilable views as to what constitutes the most advantageous practice. A notable instance is afforded by the much debated question as to whether the hole or the plug is to be taken as the standard for turned work, and as to whether tolerances should be made equally on hole and plug, or confined to the one or the other. The annual general expenses of the Association now total some 15,000*l.* yearly, as against 3,000*l.* to 4,000*l.* per annum in pre-war times, and further assistance is badly needed. The main committee, Mr. C. le Maistre pointed out, does not initiate standardisation, but waits for pressure from outside and then calls a representative conference to ascertain whether there is a general agreement as to the need for fixing an official standard.

ABRASIVES FOR GLASS.

In the course of a paper on "Abrasives and Polishing Powders for Glass," which Dr. J. Weir French contributed to a joint discussion on "Powders," held by the Faraday Society and the Oil and Colour Chemists' Association, on March 9 and 23, Dr. French stated that remarkably small forces sufficed to rupture the surface layer of glass. When a steel ball was pressed on glass, a crack encircled the area of contact, and a cone of fracture developed when the pressure was increased. That cone fracture, which Dr. French studied by means of polarised light, was fortunately rare in the common process of abrasion, which the conchoidal fracture of glass rendered possible. In abrasion by steel shot the loaded tool drove the steel balls against the glass edges, tearing off splinters, the size of which increased with the size of the balls. Rough tools of soft cast-iron or brass were preferable to hard steel tools which did not grip the grains so well. Diamond splinters were more effective, because harder, as abrasives than carborundum; emery was less suitable because it disintegrated and clogged, "losing its cut"; rounded sand grains also broke down. Grinding wheels of carborundum and other substances acted like loose abrasives, when amply supplied with water, but could not compete with loose abrasives as to the rate of abrasion. That polishing was different from abrading was pointed out by Rayleigh, who drew attention to the pool-like character of small polished areas on the surface of semi-polished glass, and to the fact that there were no transition stages. As regards glass the term "polish" was somewhat indefinite. It was almost impossible to obtain a piece of glass that had not a polished, though quite irregular, surface. When glass was suddenly ruptured, the surface would look matt, but the microscope showed the formation of minute conchoidal cavities, molecularly regular. A ground-glass surface consisted of small cavities whose surfaces were polished; in optically-worked glass the surface was not only polished but free from depression. The polishing tools were made of pitch, wax, hard felt or paper, the best agent used was rouge (ferric oxide). Black oxide of iron (so-called "glassite") was not neat; putty powder (tin oxide) was prohibited as poisonous; oxide of aluminium ("diamantine") was not so easily levigated as rouge; manganese dioxide was good, but blackened the skin. The oxidic character of these materials was not essential; carborundum, itself not recommendable for polishing, became so by being treated with hydrofluoric acid and mixed with oil as medium; carbon also answered. The final polishing was best done simply by water. It was often said that the scratches, which most polished surfaces displayed when etched, were initial scratches which the polishing had covered with an amorphous surface layer, and which only became visible after dissolving off this layer. But percussion cracks or grooves would develop if any

hard substance were gently drawn over a polished surface; the cracks remained quite invisible until they were opened out by the etching, and they flashed into view the moment the etching vapour struck the glass surface.

THE INSTITUTION OF MECHANICAL ENGINEERS.

BRITISH AND AMERICAN LOCOMOTIVE DESIGN AND PRACTICE.

THE adjourned discussion at the Institution of Mechanical Engineers, on the paper entitled "British and American Locomotive Design and Practice," by Mr. P. C. Dewhurst, was taken on Friday last, the 24th inst.

Mr. A. E. L. Chorlton, C.B.E., opened with the statement that the great distinction between the American and the British locomotive lay in the size of the boiler; to an outsider this was a fundamental difference, and it did not appear to be satisfactorily explained. The British locomotive engineer always complained of the restrictions of the loading gauge and the axle loading as the fundamental factors which had prevented him from following American practice; it being agreed, presumably, that the larger boiler was the more economical. To the outsider the British locomotive engineer did not appear to put on as large a boiler as he might. On the Great Western line one locomotive was running which had a grate area of 25 per cent. to 30 per cent. more than the standard engine, but the use of so large an area had not been applied to other locomotives. He therefore rather wondered whether the greater economy claimed for the larger boiler was really a fact.

He would like to ask if the limiting load per axle was the dead load limit set by the permanent way engineer for the locomotive designer? Was it to be understood that the spring loading must not exceed 18 tons or 20 tons? Was not account taken of the loading set up by the action of the unbalanced forces? Some very interesting experiments—he believed by the Pennsylvania Railway—had been carried out in which high grade alloy steels had been used to reduce the weights of parts, and so to reduce the out-of-balance forces. He understood that, in effect, it was found possible by their adoption to raise the loading of the axles much above the 20 tons that had been customary. The point seemed to him a fundamental one. The use of high grade steels had not been mentioned in the paper, but doubtless locomotive engineers had used such steels for various parts of locomotives, and a statement on the subject would be useful.

Mr. J. D. Twinberrow referred to recent investigations by a French engineer in which the latter drew a close parallel between the oscillations of a locomotive on the track and the movement of a ship in a seaway. When a locomotive became inclined, more weight was brought on to the springs on the low side, and the springs on the opposite side were relieved. The vertical resultant of the spring reaction was displaced towards the low side, and would intersect the normal resultant for level conconditions at a point some distance from the centre of gravity. The distance between this point of intersection and the centre of gravity measured vertically was the metacentric height. If the distance were considerable the righting moment would be strong, the period of oscillation would be rapid and the motion uncomfortable. In a ship this would cause discomfort to the passengers; in the case of a locomotive at high speed the fireman would have difficulty in firing.

It was possible to calculate the period with which a locomotive will oscillate on its springs. If the centre of gravity could not be placed exactly where it was wanted, the desired result might be obtained by other means, i.e., increasing the flexibility of the springs or bringing the centres closer together. As the metacentric height was shortened, the period of oscillation was lengthened and consequently enabled the locomotive to ride more easily. It was necessary to arrive at a compromise between instability and steadiness, and generally speaking stability must be sacrified to steadiness.

A very similar relation existed in connection with the fore and aft movement. The righting moment produced by alteration of the immersed portions, in the case of a ship, would, in the spring-supported vehicle, be obtained by independent springs. These observations led up to the author's comments on the merit of spring equalisation. If the springs were equalised right away through the locomotive, naturally there would be no stability, and any alteration of trim would make the locomotive pitch forward. The only system of equalising was to connect the whole of the springs combined in the running gear into two complete groups, neither more nor less, no matter what the number of axles on the locomotive.

The author's comparison between bar and plate frames had been limited too much to the frames as separate pieces. But the complete frame consisted of two longitudinal members with a number of cross-connections. In the case of the bar frame of American locomotives, it was usually found that, in addition to the bumper and the drag box at the rear end, there were three or four vertical plates attached to the cross-stays on the main frames, and to the underside of the boiler barrel. These plates did not hinder the longitudinal expansion of the boiler, but added enormously to the lateral strength of the frame. In a well-built American locomotive, say, with a boiler 7 ft. diameter and $\frac{7}{8}$ in. plating, he thought it more probable that the track would spring than the structure of the frame. It appeared to him that the true principle was to make the wheel base flexible, to meet the requirements of the minimum curve and to make the frame as stiff as possible with minimum weight. In a standard six-wheeled engine characteristic of British practice, built some few years ago the frames did not consist of two plain slabs continuous from end to end and just united near the two ends of the locomotive, but were stiffened from front buffer to footplate by means of the outside running board which formed a horizontal girder which prevented any considerable lateral deflection of the frame. In more recent cases he considered that larger engines had been built without sufficient bracing to counteract the loss of the side stiffening possessed by the older engines.

In the case of engines built with outside framing and large wheels, obviously there was no possibility of fitting a cross-stay to the frames within the space occupied by the wheel diameter. Many such engines within a few months after entering service had started developing cracks, from the top corners of the horn opening. The author had also remarked upon the nosing of outside cylinder engines owing to the position of the cylinders. He (Mr. Twinberrow) failed to see how a rigid frame could be made to nose by means of the steam pressure on the pistons at slow speeds, because the whole thing was in perfect balance; as long as the speed was slow inertia forces did not come into play. If nosing existed it was a sign of slackness or an abnormally yielding frame. With rise of speed, of course, the inertia forces came into play. The three-point method of support was very popular in America, but he did not commend it; for really high speeds, ranging from 60 m.p.h. to 75 m.p.h., or more, it was desirable rather to increase the stability base than to diminish it by the triangular plan of springs. In comparing the Adams' type of bogie centres and the ordinary American swing link type, the main difference was, he thought, that in the case of the swing link the friction in traversing the bogie was much less, perhaps about 12 per cent. of the sliding friction of the Adams' pattern. In both cases if the Adams' pattern were controlled by laminated or helical springs and the suspension effected simply by the inclined reaction of the load through the springs, the bogie control would be harmonic, and responsive to anything which might give rise to synchronous oscillation at higher speeds. It was better to make the bogie control aperiodic. This could be done if the springs, instead of being of the helical or laminated type were made of a suitable volute form, in which the coil of the volute seated itself on the abutment progressively, from the external diameter towards the inner, as the load was increased. Owing to the difference in the characteristic of this type of spring, it was impossible for it to vibrate throughout its stroke in unison with a given repetition of external impulse.

Mr. W. P. F. Fanhangel remarked with regard to the great difference in the construction of American and British locomotives, that it was customary for the American erector to begin with the cylinders, whereas in England the start was made with the main frames. The cylinders being such an integral part of the locomotive, if anything went wrong with the American locomotive practically the whole thing had to be dismantled. By means of a sketch on the blackboard Mr. Fanhangel described how American bar frames failed at the point where the lower front rail is spliced to the main frame.

On the subject of horn-stays, he would ask which was considered to be the best practice for the English locomotive. Something was to be said for all types, and he was unacquainted with a really perfect hornstay. If the distance-piece was not a very good fit the through bolt could be tightened up a good deal and the frame stressed. The frame and horn then broke off across the bottom corner. He thought steel tubes were certainly not much good for copper boxes. In America boxes were used made of very mild steel, and the tube could be welded in. A copper ring was put round the tube, and over that the tube was beaded and welded, thus avoiding the use of the tube expander. The author had omitted all reference to wash-out plugs, which he regarded as a matter of great importance. Unless these plugs were placed in suitable positions, there would be trouble with the boilers. Another point of interest about American locomotives was that their smoke-box door plates were about two-thirds the size of those used for British locomotives. He wondered, in this connection, how the lower tubes were got at.

Mr. George Watson said he felt that British locomotive engineers would do better to take their own course with relation to goods traffic than to imitate American practice of long trains. In America mechanical stoking had been employed, on the large locomotives especially; he would be glad of information on the point. From the damage done by sparks from moving trains, he concluded there must be a large escape of unburnt coal. There was, he thought, room for improvement in the matter of fire boxes; the grate was down below the stoker, who could not attend to it easily. No reference was made in the paper to any attempt to alter the pattern of the boiler and fire-box. In Belgium he understood great economies were claimed for the use of fire boxes with firebrick linings, the water space round the fire-box being abolished.

Mr. G. V. O. Bulkeley said the author had remarked that the best locomotive could be evolved by a combination of the best points of each practice—British and American. He submitted that that axiom was already justified by present practice. For instance, the Great Western exhibited the following community of features with American practice: (1) The boiler was of larger diameter at the throat than at the smoke-box end; (2) the smoke-box was a circular extension of the boiler; (3) the arrangement of blast pipe and smoke stack were similar; (4) the cylinders were outside and their two castings also formed the front anchorage for the boiler; (5) the springs were compensated in certain cases; (6) the outside motion bar brackets were bolted to a yoke extending right across the engine, bolted to both boiler and frame; (7) inside valve gear was employed with outside cylinders having piston valves above them, the valve spindles being actuated through the rocking shafts; (8) a two-wheeled leading pony truck was used with a medium-sized driving wheel in fast passenger traffic; (9) the cylinders were invariably set dead horizontal. The last-mentioned point was an important one, and undoubtedly led to a smooth-running engine. He thought that if independent engineers on both sides of the Atlantic produced efficient locomotives embodying points of resemblance, those points must be the hall mark of good design.

One of the most marked differences in British and American practice had been in the design of valve gears, generally speaking. The Great Western Railway was an exception in this country. Over here the long travel which was aimed at on the other side of the Atlantic was not given

to valves. With the ordinary Walschaert valve gear, the limit of valve travel was about 7 in. with the ordinary link, owing to the angularity of the link. Owing to the difficulty of getting the link on the dead centre longer links had been adopted in America and Canada. Mr. H. O. Young, the eminent locomotive valve gear specialist in America, recommended valve travels of no less than 9 in., in preference to using larger diameter piston valves in order to get a free exhaust clearance. Locomotive valve gear development in America and Canada dated, generally speaking, from Dr. Goss' work at the Purdue University Locomotive Testing Plant. While it was easy to get steam into the locomotive cylinder, it was less easy to get it out freely. American valve gear design aimed at a full port opening to exhaust, when the port at the opposite end of the cylinder was about $\frac{1}{4}$ in. open to steam; hence the long valve travels, resulting certainly in very free running engines and also long steam laps, which the long travels allowed to be used.

He had been interested in what had been said about the metacentric height. While the transverse metacentric height might vary from 1·6 ft. in a torpedo boat destroyer to 6 ft. in a bigger boat, the longitudinal metacentric height might be 60 ft., 70 ft. or 100 ft. From this it followed that any change of trim in the fore and aft direction would not affect the longitudinal metacentre to anything like the extent that a change would affect the transverse metacentre. He assumed that the same remarks would apply to the locomotive. On the subject of curves, while he was in the employ of the Canadian Pacific Railway at Montreal, a Mallet articulated locomotive was designed for use on the Rocky Mountains, where the curvature was as much as 15 deg. A number of 15 deg. curves of standard 100-lb. rails were laid down in the works, but until the curving spring adjustment was made right the trial curves used to snap off like pipe clay, which gave some idea of the force of curving in a large engine. Eventually, when the curving adjustment was made quite right by experiment, there was only $\frac{3}{64}$ in. wear on the flanges of the leading wheels of the Mallet engines after 4,000 miles running; the engine took the curves very easily. The fact had been mentioned that with bar framing a crack often occurred just at the frame splice. The chief mechanical engineer of the Canadian Pacific had, in his latest engines, doubled the thickness of the framing at that very point. This was the more interesting since, for several months in the year, the Canadian Pacific Railway engine ran over frozen ground.

Mr. H. P. Renwick, of the Great Indian Peninsula Railway, observed that the author had stated that it would be interesting to see the short large-diameter blast pipe tried on express work in England. On the Great Indian Peninsula Railway many experiments in that direction had been carried out. On a 4-6-0 type of engine, with cylinders 21 in. by 26 in., the original design of blast pipe allowed for a diameter of top of $4\frac{3}{4}$ in. The blast pipe top was 3 in. below the boiler centre line, and a petticoat 12 in. high, 20 in. in diameter, at the bottom, tapering to 14 in. on top, was provided. A wire cone-shaped spark arrester extended from the blast pipe top to the bottom of the petticoat, and another spark arrester covered the area of the smoke-box at the bottom of the petticoat. After various experiments had been made, it was ultimately found that the best results were obtained with a blast pipe 1 ft. $\frac{1}{2}$ in. below the boiler centre line, with an internal diameter of blast pipe top of $6\frac{1}{2}$ in., with four 1-in. triangular lugs, and a straight petticoat, 1 ft. 5 in. in internal diameter, with its bottom edge $4\frac{5}{8}$ in. above boiler centre line and connected to the base of the chimney; no spark arrester was provided. In addition, certain alterations were made to the valve gear, which provided a maximum cut-off of 60 per cent., instead of the normal 85 per cent., and a minimum normal cut-off of as little as $12\frac{1}{2}$ per cent. In general working the blast was almost inaudible, and as much steam as required was obtained; the coal, undoubtedly, was burnt more slowly and the coal consumption dropped. He considered that by increasing the blast-pipe diameter and by roughening, marked advantages were achieved.

Mr. James Clayton, M.B.E., of the South-Eastern and Chatham Railway, said the author recommended the greater use of eight-coupled and even ten-coupled locomotives, basing his reason apparently on the question of axle weight limits. He (Mr. Clayton) thought the more important factor was the distribution of a large weight over a very limited wheel base, which so sorely tried bridges of the larger span. It was that which prevented a more extended use of eight-coupled and ten-coupled locomotives in this country, and there the bridge engineer could help. With regard to the high-capacity, low-tare wagon, he felt that the terminal facilities, wharf length, dock and warehouse accommodation, &c., had more to do with the use of such wagons than the bridges. He thought that outside cylinders were more likely to cause nosing of the engine than inside cylinders, owing to the greater distance between centres. He agreed that control by the bogie influenced nosing. In the latest engines on his line, the 2-6-0 and the 2-6-4, which were fairly long engines, a two-wheeled truck was used in front. The Cartazzi principle had successfully been used and gave exactly the dead control required in a bogie. Too flexible a side control, such as the use of helical springs, and sometimes laminated springs, afforded, was not desirable. The two types of engines he had named had been running for $4\frac{1}{2}$ years, and nothing had to be done to the bogies, beyond attention to the bearings.

He regarded favourably the American practice of providing good surface between the axle-box and wheel face; several of the larger British lines had also adopted the practice, with beneficial results. If compensating improved the riding of an engine on a rough road, the wear and tear of British engines, riding over fairly good roads, should be much reduced by it. With regard to the Belpaire fire boxes on British railways which had previously used "crown" bars, his railway was an exception. The old Stirling boilers were all of the round-top type stayed by straight direct stays. These were followed by crown stays for a short time. Belpaire boxes were now fitted, among other reasons because one flat surface was best stayed to another flat surface. The drop-plate had been tried in British practice with long grates, but the drop-plates constantly got stuck, and they were given up. With regard to the advantage of the pilot valve in the sliding type of regulator, he saw some difficulty in providing the amount of leverage required to move the regulator valves in use with boiler pressures of 220 lb. to 225 lb. without the pilot valve, which seemed indispensable. The pull-out handle had one disadvantage, namely, that unless used with a long control it was a dangerous type. The cross-movement handle could be arranged conveniently for the driver.

He agreed that the cone-spherical joint was preferable to the asbestos and special copper and asbestos joints for superheater elements. A good type of joint was the double-vee type. On his line dampers for superheaters had not been used since 1914, and no bad results had followed; they did, however, use the automatic air inlets, and there was no trouble with lubrication. The smoke-box diaphragm plate was a good feature. With regard to the large smoke-box door, this had many advantages. It was handy in the detection of leaks by inspection, and for cleaning the box and tubes; the tubes could not be so readily cleaned from the fire-box end; the boiler had to cool first, and there was liability to jam cinders further in. He could not see much advantage in the roughening of the blast; the South-Eastern Company had tried the plan without achieving the effect claimed. A plain orifice made to suit the length of the chimney was best; it should not fill the chimney, but should leave $1\frac{1}{2}$ in. to 2 in. round the column of steam. The British "combination" pattern of injector he considered was of no use here; the water in this country did not suit it. The injector had given trouble on the Great Northern engines, and eventually a flooded type of injector had supplanted them. He regarded the joint with spherical surfaces, Fig. 10 (*b*) of the paper, as bad, because of the danger of jamming the regulator rod in the stuffing-box. The British stuffing-box with a flat metal-to-metal joint was the best. He wished the author had compared maintenance and upkeep costs. He found that in some 60 per cent. of the points enumerated by the author, the latter had agreed with British practice, while he had also admitted the coal-saving virtues of the British locomotive.

Major P. J. Cowan, M.B.E., referred to the author's statement that comparatively little use was made of tank engines in America. American designers generally objected to tank engines on the score of the variable adhesive weight; that, he believed, was the chief reason. A tank engine cylindered up to the limit for full loaded conditions of bunker and water tank would tend to slip when the tank and bunker were empty. On the other hand, if the locomotive were only cylindered for light conditions—tanks and bunker empty—full advantage could not be taken of the permissible adhesive weight. That was a point of importance in connection with shunting engines, where, as in America, very large units had to be dealt with.

The author spoke of the narrow fire-box difficulty produced by using bar frames. He considered that the author had charged bar frames with something for which they were not responsible. In the old days, in America, fire boxes were dropped between the frames. Between that phase and the present use of wide boxes, however, there was a period during which the boxes were placed on the top of the frames, giving a box at least 42 in. wide inside, as against the British box of about 40 in. width. The Americans had been driven to the use of wide fire boxes because, as boiler capacity had to be increased, their grates ran to inordinate length. If the boxes had been placed between plate frames the length would have had to be even greater. If the grate area which a Pennsylvania engine possessed to-day had had to be arranged between plate frames it would have to be something like 19 ft. long—quite an impossible length. The Americans undoubtedly appreciated the advantages of wider and shorter boxes. That the question was not wholly related to the use of idle trailing wheels, was clear since the Pennsylvania box to which he had referred and which was about 9 ft. 6 in. by 6 ft. 8 in., was used over coupled wheels.

The author stated that the wearing surfaces of horns were less in American than in English practice. Mr. Sanderson had already pointed out that with the heavy frames and big engines of the present day, this was not the case. Even with the smaller frames and lighter engines, the difficulty could be overcome, if necessary, by setting the centres of the frames in. It was a perfectly easy job in designing if a wider box and more wearing surface were required to increase the thickness of the wings of the shoe and wedge. That simply involved bringing the centres of the frames further in. That that could be done was proved by the fact that with the large engines it was necessary to arrange for frames of a width of 7 in., as compared with the lighter engines having frames only 4 in. wide. In the large engine, with 7-in. frames, the frame centres were about 41 in. apart, whereas in the old and lighter engines, with frames 4 in. thick, the centres would be 47 in. apart. Reference had been made by the author to the fact that both main crank pins and the side rod pins were, in American practice, large. They had, in fact, now become so large, on the larger engines, that trouble had arisen from the high rubbing speed. Drawings were given in the paper of various methods of fixing bushes in the side rods, but it was interesting to note that since 1912, instead of fixing bushes, Americans had adopted the practice of using floating bushes, *i.e.*, bushes free to revolve. By the kindness of the American Locomotive Company, the speaker then proceeded to give particulars of the use and behaviour of such bushes, but as this matter is more fully dealt with on page 388 of this issue we need not repeat the information here. In conclusion, Major Cowan referred to the author's statement that "long after the time when cast steel came into favour in British practice, cast-iron continued to be used in America." He thought that, in justice to American practice, it should be remembered that while we in England had to go to Germany for sound steel castings for steel wheel centres when they came into favour here, at that same time the Americans were both casting and

THE HOTCHKISS-TAYLOR SYSTEM OF TANGENT RACK GEARING.

(For Description, see opposite page.)

Fig.1.

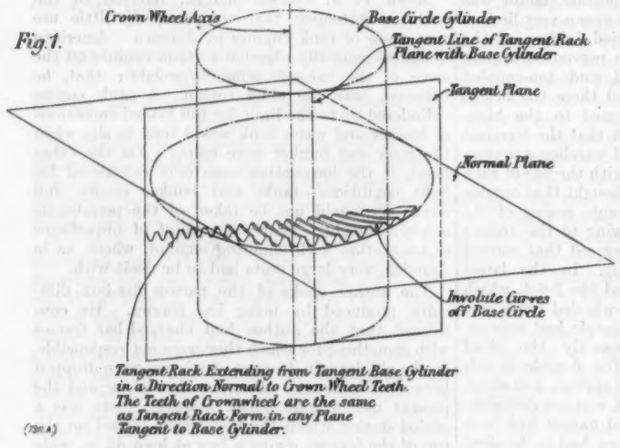

Crown Wheel Axis
Base Circle Cylinder
Tangent Line of Tangent Rack Plane with Base Cylinder
Tangent Plane
Normal Plane
Involute Curves of Base Circle
Tangent Rack Extending from Tangent Base Cylinder in a Direction Normal to Crown Wheel Teeth. The Teeth of Crownwheel are the same as Tangent Rack Form in any Plane Tangent to Base Cylinder.
(7316 A.)

Fig.2.

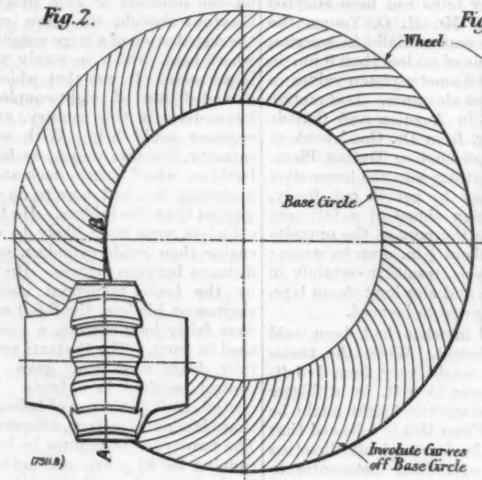
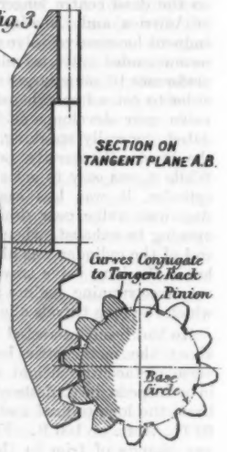


Fig.3.



using steel wheel centres of a very sound and excellent quality.

Major C. E. Williams thought the chief reason for buying locomotives in America rather than in this country was to obtain some advantage in price or in delivery, and not in design. If the author's ideas of design were adopted, the advantage in first cost would be lost and delivery would be protracted. For Colonial service, he believed in buying American locomotives, giving the builders as much latitude as possible, stipulating only in relation to essentials such as the wheels, load per axle, &c. Some time ago he had been concerned with the ordering of 10 locomotives for one of the Crown Colonies, and quick delivery was absolutely essential. Leading requirements only were specified. Those engines were now running side by side with a similar class of engine built in this country, and he would quote from the railway authorities' report on these engines, in substance as follows: From a purely mechanical standpoint, the British-built engines, from the point of view of construction and economy in fuel consumption, were undoubtedly preferable to the American engines. With regard to construction, the American engines had failed in a point where the British locomotives were eminently preferable, namely, boiler practice. With regard to fuel consumption the British engines showed the distinct advantage of 78 lb. of coal per train-mile against 84 lb. per train-mile consumed by the American locomotives. Oil consumption was, however, in favour of the American locomotive. The British engines were, Major Williams said, to be preferred. The one great advantage of the American locomotive was the rapidity with which it was delivered. He thought "contracting shops" in that country were less conservative than the British railway shops, and so combined the best British and best American practice. He agreed with the author in thinking that damper gear, cleading sand boxes, and other parts, did not in American practice, receive the same care and attention as they did in engines of British design. Colonial practice had long aimed at as large and roomy a cab as possible with, if practicable, protection from the sun in hot climates, while every endeavour was made to keep the cab as far back from the boiler as possible. The agents for Crown Colonies specified metal-to-metal joints, and these could not be regarded as American practice.

After Mr. Edmund White had remarked upon the use of large engines in the early days of the Great Western Railway, Professor P. M. Baker said he thought that the problem of the large and heavy engine did not turn on the bridges or the track, but on the use of stronger coupling gear and effective brakes.

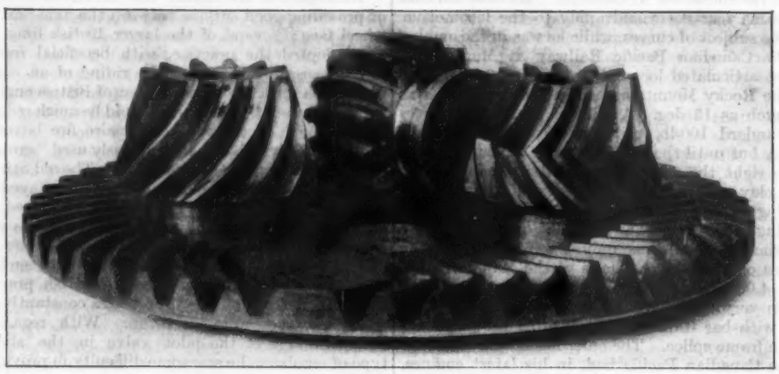


FIG. 4.

FIG. 5.

The President remarked that years ago, when consulting engineer to the Lancashire Agricultural Society, much discussion took place on the subject of spark arresters, and he had been asked to report. In spite of the regulation for the provision of efficient spark arresters, he had been able to collect a large number of cinders, from the different parts of Lancashire, which had evidently evaded the arresters. His experience had shown that the drivers removed spark arresters from their engines, because of the interference with the steaming caused by these arresters.

Lieutenant-Colonel E. Kitson Clark then briefly touched upon two or three points arising out of the discussion, stating that with regard to the action of unbalanced forces, that question was being considered in relation to the strength of bridges in India. The actual static weight of the axle load was ceasing to be considered the final arbiter. The unbalanced parts had been made much lighter by the introduction of high-quality steel. With regard to the position of the fire-box, the Austrian practice was to perch the fire-box right on the top of the frames, with the boiler centre 10 ft. above the level of the rails. In such case the question of the metacentric height would be particularly interesting. The engines ran very comfortably, and so long as it was not dangerous the practice was wise. The position on the top of the frames afforded facilities for getting at the stays, none being hidden behind the frames—an admirable thing. Before very long it was to be expected that

THE HOTCHKISS-TAYLOR SYSTEM OF TANGENT RACK GEARING.

FIG. 6.

FIG. 7.

FIG. 8.

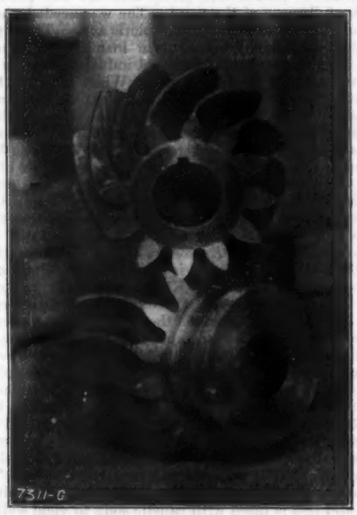


FIG. 9.

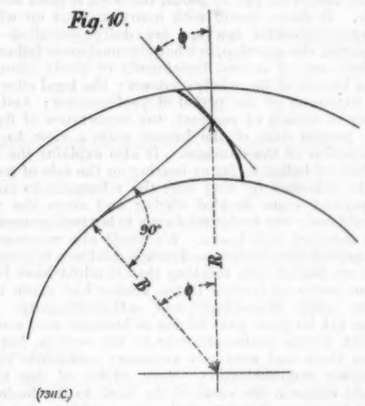
rustless steel would be in use for locomotive frames, cabs, boilers, &c., getting rid of that very expensive item—painting. The equal turning movement was so obvious with the three or four-cylinder that that type was likely to come to the front when the internal-combustion engine, for which all were looking, arrived.

The President then closed the proceedings with the announcement that to-night, Friday, March 31, an extra general meeting would be held, when a paper entitled "Milling of Screws and other Problems in the Theory of Screw Threads," would be read.

THE HOTCHKISS-TAYLOR SYSTEM OF GEARING.

THE basis of the usual forms of gearing is a linear rack of which the teeth are made with profiles either involute, cycloidal or as desired. In the Hotchkiss-Taylor system which we illustrate in Figs. 1 to 10, on page 400 and above, and which is being introduced by Messrs. Hotchkiss et Cie., Gosford-street, Coventry, the rack is arranged in a plane tangential to a cylinder, as shown diagrammatically in Fig. 1 and in Figs. 2 and 3. The basic gear form of this system is a crown wheel, the

Fig. 10.



(7311 C.)

teeth of which are involute curves in a plane normal to the axis of the crown wheel. They are of the same profile as the rack teeth in a plane parallel with the axis. Fig. 1 shows the crown wheel involute curved teeth, and to the left an extension representing the tangent rack of similar tooth profile. A crown wheel and rack are shown in the photograph reproduced in Fig. 4. The distance of the parallel plane from the cylinder axis is the radius of the base cylinder used for the generation of the involute curves in the plane normal to the axis. The rack form of tooth extends from the tangent line of the tangent rack plane with base cylinder in a direction normal to the tooth curves in the normal plane. This will be followed in Figs. 1 and 4.

In order to make a distinction between this system and the linear rack system of gearing the term tangent rack has been adopted. Figs. 2 and 3 show a crown wheel and pinion developed on this system, while Fig. 5 is merely a group showing different forms which may be worked out with it. These include spurs, spiral bevels and double helical. It is an interesting feature that any gear in the tangent rack system, whether cylindrical or conical, can be meshed, with any other provided it is conjugate to the basis tangent rack crown wheel, and base circle or normal pitches are equal. This is not the case with the linear rack system in which worm, spur or spiral gears will mate providing the normal or base circle pitches are equal, but conical gears and bevels will not mesh with cylindrical gears. Figs. 6, 7 and 8 show a series of gears developed on the tangent rack system. Figs. 6 and 7 show respectively a spiral bevel, and a double helical bevel set, with intersecting axles, while Fig. 8 shows a spur set. It is further possible to produce bevel sets with non-intersecting axes, and worm gear whose axis lies in the tangent plane A B, in Fig. 2, meshing with the crown wheel. Between the limits of, on the one hand, such a worm, and on the other, the spur whose axis is normal to the tangent plane, spiral gears can be produced. It is possible to produce in this system as many forms of gear as are made with the linear rack system, and when the involute form is adopted for the tangent rack the same elasticity is obtainable for tooth proportions and pressure angle as is obtained in the linear rack gear. Fig. 9 shows a spur gear in mesh with a spiral bevel.

In designing Hotchkiss-Taylor tangent gears the portion of the involute curve chosen is that which gives the mean angle of the spiral required as indicated in Fig. 10; $\phi = \cos^{-1} \frac{B}{R}$, where B = the base circle radius, and R any point on the involute curve.

The spiral of tangent bevel gears is involute, and in action the load component of the torque is applied tangentially to the base cylinder at any position of engagement of the pinion teeth with the crown wheel. This is somewhat similar to the action between linear involute spur gears in which the contact takes place on the line of action in a plain tangential to the base cylinders of the two gears in mesh. This feature is conducive to quiet running, since the angular velocity is constant, and the transfer of the load along the spiral, as well as down the face of the tooth, is at a uniform rate. The normal pitch thickness of the tooth and spacing are constant, being the same as the base circle pitch at any position along the tooth spiral. This enables both sides of the teeth to be generated by the passage of the cutter.

If a section, Fig. 3, be taken of a crown wheel in a plane A B tangential to the base circle (Fig. 2) the teeth in section will have the same profile as those of the basis rack, so that a correctly generated pinion can be rolled along the face of the crown wheel in the same way that a linear spur gear can be rolled along the linear rack. The tooth curve of the pinion, taken on the mid-section, in a plane normal to the axis is therefore involute, cycloidal or conjugate to any other suitable curve chosen for the tangent rack. The spur shown in section in Fig. 3 is of involute form.

The end thrust with this system of gearing is small in the case of crown wheels, and practically nil in the case of the pinions, being due to the rack section pressure angle only, so that heavy thrust bearings are not required. For tangent involute worm gears it is desirable to employ a fairly high pressure angle, in order to mitigate the interference which would otherwise occur arising from the curvature of the crown wheel teeth.

GERMAN DIESEL TANKER FOR ITALY.—We read in *Motorship*, New York, that an order has been secured by the Deutsche-Werke of Kiel (not to be confused with the Deutsche Werft of Hamburg), for a twin-screw motor tanker for Italian shipowners, in which two of the new Deutsche-Werke four-cycle Diesel engines are to be installed.

INDUSTRIAL NOTES.

THE result of the ballot taken by the 47 engineering trade unions which are outside the Amalgamated Engineering Union, but which, like the latter, are involved in the question of managerial rights, was announced last Saturday. The figures were, against acceptance 164,759; in favour 49,503, or a majority against of 115,256. In considering this result, due note should be given to the fact that the ballot was taken at a time when the Amalgamated Engineering Union members were locked out for having declined to agree to the same proposal, namely, the right of the employers to exercise managerial functions in their establishments. Conferences have been held almost continuously since the trouble began, and it was hoped at one time that the difficulty which separates both sides had been overcome. At the conference held last Tuesday there occurred a difference of opinion between the 47 unions and the Amalgmated Engineering Union as to the question of the cancellation of the lock-out and the consideration of the points in dispute. Following upon the failure of the discussion, the employers stated they were forced to the conclusion that the only way was for them to post the notices in the case of the other unions, so as to bring their members to the same position as those of the Amalgamated Engineering Union. The employers accepted this conclusion with regret, and added that they had not been assisted by the Negotiating Committee of the unions to any alternative. The men forming part of the 47 other trade unions in question are therefore to be locked out also.

Towards the end of last week a conference of the shipbuilding trade unions was held at the Ministry of Labour in order to consider the claim of the employers for a reduction of the weekly war bonus by 10*s.* 6*d.* from the 29th inst., and by an additional 6*s.* from April 26. It was decided at the conference to take a ballot on the above terms and the ballot papers were sent out. The unions asked the employers to postpone the operation of the employers' notices for a week, so as to enable the ballot to be completed while the men are still at work; they also asked the Minister of Labour to intervene with the employers so as to secure postponement of the notices. The employers declined, and the operation of the notices being maintained, the men, acting upon instructions from the shipbuilding unions, suspended work last Tuesday evening pending the result of the ballot.

The ship-repairing firms on the Mersey having decided to put in force the same reductions in the weekly war bonus as those notified by the shipbuilding firms, the local trade unions met to consider the matter and decided that they had no alternative but to recommend their members to refuse to work under the new terms. A ballot of the ship-repairing men is also being taken.

In the meantime orders for new ships and for ship repairs are continuing to be placed abroad.

With reference to employment at Woolwich Arsenal and to the locomotives recently built there, Sir F. Banbury, speaking in Parliament last Friday, said that during the most expensive period of the war one of the leading railway companies paid to a private firm of locomotive builders 12,425*l.* for an eight-coupled goods engine, as compared with 16,000*l.* for the engines made at Woolwich. He thought that as the men in the Arsenal had been receiving high wages in the war they should have saved money for the time when they would no longer be required, in order to tide them over till they could get other employment. Sir F. Banbury asked what was going to be done with these engines; as far as he knew there was no demand for them in England, the railway companies having more engines than they wanted. The only ray of satisfaction was that the building of locomotives at Woolwich had turned out so disastrously that nothing of the sort could be attempted again. In the course of his reply, Sir L. Worthington Evans said that 45 locomotives were now available, and he would be prepared to go to a considerable loss to dispose of them. He added that it was not the policy of the Government to go in for trading operations at Woolwich or elsewhere.

It having been suggested in mining districts that the coalowners have manipulated the figures given under the heading of "costs other than wages," the Mining Association has issued a statement to the effect that the owners' profits no less than the men's earnings depend upon efficient and economical working. The association adds that within the last fifteen months the cost per ton of timber and stores has been brought down from 6*s.* 5·33*d.* to about 3*s.* "Other costs," which include staff salaries, depreciation and repairs, pensions, local rates and welfare levy charges, are outside the control of the owners, and as most of them do not vary greatly it has not been found possible to effect reductions to any extent. Apart from this consideration, the miners are adequately protected by the terms of settlement, which have provided that all items of cost shall be considered by the National Board, which shall decide whether they shall be included in the costs of production other than wages. In disputed cases the matter is referred to the independent chairman for decision. A still more important safeguard furnished by the agreement is the authorisation of a joint test audit of the owners' books, which is undertaken periodically by independent accountants appointed by each side. This ensures a thorough examination of the colliery accounts by experts acting in the men's interests, and is an effective check against irregularities in the making up of costs.

The owners, it is further stated, are considering whether it is possible to give information in a more detailed form to the men. This would probably involve trouble and expense, but they are anxious to prove to the satisfaction of the workpeople that any suspicion which may prevail in the districts is groundless.

NOTES ON NEW BOOKS.

IN "*Commercial Contracts: An Exposition of the Law for Business Men*" (London: Sir Isaac Pitman and Sons, Limited, 5*s.* net), Mr. E. J. Parry has endeavoured, as is indicated in his preface, to expound the main points and difficulties in the law of the contract of sale in a manner as little burdened with legal technicalities as possible. The difficulty inherent in such a task is that if the book is sufficiently elementary to be read and understood by the average business man it can have little prospect of being read as a legal treatise, and if it attempts to give an adequate exposition of the law it may be difficult to get business men to take the trouble to read and understand it. As a brief exposition of the leading points in the law of the sale of goods, the book is most admirable. It deals clearly with many matters on which busy commercial lawyers are daily consulted—for example, the question, in what circumstances failure to deliver one of several instalments of goods amounts to a breach of the whole contract; the legal effect of an extension of the period of performance; and, in cases of breach of contract, the importance of fixing the precise date of the breach with a view to the estimation of the damages. It also explains the law of bills of lading so far as bearing on the sale of goods to be delivered by sea; and the references to many important cases decided during and since the war should make the book useful even to lawyers possessing the standard text books. We would also recommend it to merchants, brokers and commercial men in general, but we cannot help thinking that it might have been more useful to laymen if the author had made it a little more elementary and self-explanatory. On page 114 he gives good advice to business men not to return letters contemptuously to the writers, but to keep them and send any necessary comments by a separate communication. More advice of this kind might enhance the value of the book to the business men for whom it is intended. We would suggest also that in a future edition the Latin phrases and maxims should be translated. The chapter on shipping contracts shows signs of having been written somewhat hurriedly—for example, Lord Blackburn's definition of a bill of lading is given three times within 10 pages; and on page 108 the writer should make it clear that in referring to "section 32" he means section 32 of the Sale of Goods Act. The word "verbally" is repeatedly used in the text where "orally" is meant, and the author should know better than to use such phrases as "the question of what," "the question of whether," and "the question as to whether." We should not like to accept without careful consideration his opinion, on page 129, that it is probable that an arbitrator could award or order specific performance without being expressly empowered to do so; and we think the maxim "De minimis non curat praetor" (the court does not concern itself with trifles) is preferable to the version given on page 151, "De minimis non curat lex." The law of the land is in its nature applicable to the most trifling cases as well as to the most important, although the Courts refuse to waste their time over trifles. These are minor matters, however, and the only serious defect in an excellent book is that there is no index.

In ordinary technical practice the boundary between analysis and research is fairly distinct. The chemist asked to analyse an ore or a sugar determines the constituents of the mineral and the adulterants in the sugar by routine processes. In a good coal analysis his task approaches that of a research. Even in the proximate analysis conventional practice is very uncertain. We know that we cannot get rid of all the moisture in the coal without affecting the coal, and that moisture is really one of the "volatiles." We can estimate the ash percentage, but we are aware that the ash is very unevenly distributed, and that this distribution is of importance. The ultimate analysis tells us the proportions of carbon, hydrogen and nitrogen, sulphur (in its various compounds) and other impurities. But no method has yet been devised for the determination of the oxygen, and as regards the real constituents of coal we remain sadly ignorant. In his volume on "*The Analysis of Coal and its By-Products*" [The "Colliery Guardian" Company, 30, Furnival-street, E.C. 4, price 21*s.* net], Mr. S. Roy Illingworth, M.Sc., F.I.C., of the South Wales School of Mines, at Treforest, discusses these latter problems in a very short chapter on the Resolution of Coal into Various Components and the Action of Solvents on Coal. If he had left out the miscellaneous chapters on flash-point—in which the Pensky-Martens apparatus is ascribed to Pensky-Martin—and on the analysis of sulphuric acid and of caustic soda, possibly also the long chapter on the Analysis of Ammonia Liquor, &c., he might have had space to indicate the modern tendencies of coal research, although he would have travelled into speculative ground. The technical analyst will find useful practical guidance in the 380 pages of this volume, in the compilation of which Mr. Illingworth had the assistance of Mr. Jenkyn Griffiths, formerly of the same college, now assistant editor of *The Colliery Guardian*. The main divisions deal adequately with the Sampling—for which the method of the American Bureau of Mines is recommended—Proximate and Ultimate Analysis of Coal, Ash, Coking Test, Analysis of Coal Tar, Examination of Tar Oils, and Gas Analysis in general—a good chapter—though Professor Bunte may be astonished to find his name spelt with an accent over the "e"—Calorimetry and the Control of Combustion. Literature references are very scarce. Sir Robert Robertson, F.R.S., the Government Chemist, has written a foreword.

Synthetic phenol and picric acid are war products in the full sense of the word. The war needed phenol mainly for the manufacture of picric acid. The supply of coal-tar phenol being quite insufficient to meet this demand, a synthetic phenol industry, new to the country, had to be developed. When later in 1917 amatol replaced picric acid as a high explosive to an increasing extent, many of the new plants closed down again. The new industry never attained the dimensions it had in France where picric acid had long been the chief military explosive, and the manufacture of the two products over here was less under the direct control of the Department of Explosives Supply than the manufactures of other explosives had been in their wide ramifications. For these reasons No. 6 of "*The Technical Records of Explosives Supply, 1915 to 1918. Synthetic Phenol and Picric Acid*" [H.M. Stationery Office, Imperial House, Kingsway, W.C. 2; price 15*s.* 7½*d.* post free] does not give such complete information as to working detail as the other volumes offered. Nevertheless, Mr. W. MacNab, F.I.C., and his colleagues in the Ministry of Munitions have compiled a very useful volume. The first large synthetic phenol plant was started by the South Metropolitan Gas Company; other private firms, Messrs. Brunner Mond and Co., R. Graesser, and British Dyes, followed later, and the Government had two factories. Of the many processes investigated the sulphonation of benzene alone answered; but it was effected in various ways. The benzene sulphonic acid is converted into its sodium salt, and this is fused with caustic soda to yield sodium phenate which decomposed with acid (sulphuric acid, nitre cake, or carbonic acid) finally yields phenol, which is distilled. In the picric acid manufacture, the phenol $C_6H_5.OH$ is again sulphonated and then nitrated; here the nitration also splits off the sulphonic acid groups so that trinitrophenol $C_6H_2.OH.(NO_2)_3$, or picric acid, is more directly produced best by Mr. Newton Brooke's continuous process. Another process, more dangerous to health, starts from dinitrophenol. The manufacture was left to firms; Government works were erected at Avonmouth, but they did not produce. Explosions were numerous; that the fume nuisance was often very serious one could gather from reports of the Alkali Inspectors issued for the years of the war.

THE AERONAUTICAL COLLECTION, SOUTH KENSINGTON MUSEUM.—Students of aeronautics and others interested in the development of aerial navigation will be glad to know that the collection of aeronautical exhibits in the Science Museum, South Kensington, has been catalogued, and that the catalogue is now on sale at the price of 1*s.* 6*d.* The exhibits are divided into sections devoted respectively to aeroplanes and models, aeroplane parts, engines and engine details, instruments, experimental apparatus, and lighter-than-air craft, and the catalogue contains a brief description of each exhibit with illustrations of several of them. It will thus greatly facilitate an inspection of the exhibits, and will also serve as a handy book of reference. Copies are obtainable through any bookseller, or post free from H.M. Stationery Office, Imperial House, Kingsway, London, W.C. 2, price 1*s.* 8*d.*

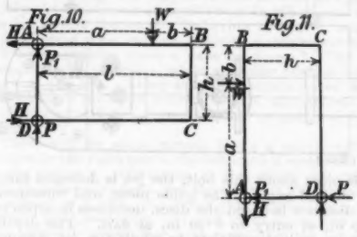
STATICALLY INDETERMINATE AND NON-ARTICULATED STRUCTURES.

By Professor F. C. LEA, D.Sc., M.Inst.C.E., M.Inst.Mech.E., M.I.M., A.R.C.S., Wh.Sc.

(*Continued from page* 352.)

CANTILEVER STRUCTURE OF THREE MEMBERS WITH PIN JOINTS AT THE SUPPORTS, FIG. 10, OR VERTICAL FRAME WITH LOAD ON THE VERTICAL POST, AS IN FIG. 11.

Let the cantilever structure be loaded at E with a load W at distance a from A. There are pin



joints at A and D, and rigid joints at B and C.

From the conditions it is at once seen that:

$$H = \frac{W a}{h}$$

and

$$P + P_1 = W.$$

The moment at the joint C is

$$M_C = P l$$

and at the joint D is

$$P l - H h = P l - W a.$$

Let the moment of inertia of A B and D C = I and the moment of inertia of B C = I_0. The total work in the structure is then:

$$U = \int_0^l (P x)^2 \frac{dx}{2EI} + \int_0^h \left(P l - \frac{W a x}{h}\right)^2 \frac{dx}{2E I_0} + \int_0^a \{W - P) x\}^2 \frac{dx}{2EI} + \int_0^b \{(W - P)(a + x) - W x\}^2 \frac{dx}{2EI}$$

$$\frac{dU}{dP} = \frac{P l^3}{3I} + \frac{P l^2 h}{I_0} + \frac{P l^3}{3I} - \frac{W a l h}{2 I_0} - \frac{W a^3}{3I} - \frac{W a^2 b}{I} - \frac{W a b^2}{2I} = 0.$$

Let

$$\frac{I_0}{h} \times \frac{l}{I} = r$$

then

$$P l^2 \frac{2r+3}{3r} - \frac{W l a}{2r} - \frac{W a^3}{3I} - \frac{W a^2 b}{l} - \frac{W a b^2}{2I} = 0$$

i.e.

$$P l \frac{2r+3}{r} - \frac{3}{2}\frac{W a}{r} - \frac{W a^3}{l^2} - \frac{2 W a^2 b}{l^2} - \frac{W a^2 b}{l^2} - \frac{W a b^2}{l^2} - \frac{W a b^2}{2 l^2} = 0$$

$$P l \frac{2r+3}{r} = \frac{3}{2}\cdot\frac{W a}{r} + \frac{W a^3}{l^2} + \frac{2 W a^2 b}{l^2} + \frac{W a b^2}{l^2} + W\left(\frac{a^2 b}{l^2} + \frac{a b^2}{2 l^2}\right)$$

$$= \frac{3}{2}\cdot\frac{W a}{r} + W a\left(\frac{a^2 + 2ab + b^2}{l^2}\right) + W\left(\frac{a^2 b}{l^2} + \frac{a b^2}{2 l^2}\right)$$

$$= \frac{3}{2}\cdot\frac{W a}{r} + W a + W\left(\frac{a^2 b}{l^2} + \frac{a b^2}{2 l^2}\right)$$

$$= \frac{(3 + 2r) W a}{2r} + W\left(\frac{a^2 b}{l^2} + \frac{a b^2}{2 l^2}\right)$$

$$\therefore \quad P l = M_C = \frac{W a}{2} + \frac{r W}{(3 + 2r) l^2}\left(a^2 b + \frac{a b^2}{2}\right)$$

$$M_B = M_C - W a = -\frac{W a}{2} + \frac{r W}{(3+2r) l^2}\left(a^2 b + \frac{a b^2}{2}\right)$$

The same result can be obtained by the method of moments.

Let M_C be the moment at the joint C and M_B the moment at joint B.

Then $M_B = M_C - W a$.

The moment at any point

E in D C is $M_C \frac{x}{l}$

F in C B is $M_C - (M_C - M_B)\frac{x}{l}$

$$= M_C - W a \frac{x}{l}$$

G between A and W $= M_B \frac{x}{l} - \frac{W b x}{l}$

$$= (M_C - W a)\frac{x}{l} - \frac{W b x}{l}$$

H between B and W $= M_B\left(1 - \frac{x}{l}\right) - \frac{W a x}{l}$

$$= M_C\left(1 - \frac{x}{l}\right) - W a$$

The total work:

$$U = \int_0^l \left(M_C \frac{x}{l}\right)^2 \frac{dx}{2EI} + \int_0^h \left(M_C - \frac{W a x}{h}\right)^2 \frac{dx}{2E I_0} + \int_0^a \left(M_C \frac{x}{l} - \frac{W a x}{l} - \frac{W b x}{l}\right)^2 \frac{dx}{2EI} + \int_0^b \left\{M_C\left(1 - \frac{x}{l}\right) - W a\right\}^2 \frac{dx}{2EI}$$

Hence we find

$$\frac{dU}{dM_C} = \int_0^l M_C \frac{x^2}{l^2}\frac{dx}{I} + \int_0^h \left(M_C - \frac{W a x}{h}\right)\frac{dx}{I} + \int_0^a \left(M_C \frac{x}{l} - \frac{W a x}{l} - \frac{W b x}{l}\right)\frac{x}{l}\frac{dx}{I} + \int_0^b \left\{M_C\left(1 - \frac{x}{l}\right) - W a\right\}\left(1 - \frac{x}{l}\right)\frac{dx}{I} = 0$$

$$= \frac{M_C l}{3I} + \frac{M_C h}{I_0} - \frac{W a h}{2 I_0} + \frac{M_C}{I}\left(\frac{a^3}{3l^2} + \frac{b^3}{3l^2} + b - \frac{b^2}{l}\right) - \frac{W a^4}{3 l^2 I} - \frac{W b a^3}{3 l^2 I} - \frac{W a b}{I} + \frac{W a b^2}{2 l}$$

Multiplying through by $\frac{I}{l}$, and noting that

$$\frac{a^3}{3l^2} + \frac{b^3}{3l^2} + b - \frac{b^2}{l} = \frac{l}{3} \text{ and } \frac{I_0}{h} \times \frac{l}{I} = r$$

and simplifying the terms in W,

$$M_C\left(\frac{2r+3}{r}\right) - \frac{3 W a}{2r} - W a - \left(\frac{W a^2 b}{l^2} + \frac{W a b^2}{2 l^2}\right) = 0$$

or

$$M_C = \frac{W a}{2} + \frac{r}{2r+3}\left(\frac{W a^2 b}{l^2} + \frac{W a b^2}{2 l^2}\right)$$

and similarly

$$M_B = -\frac{W a}{2} + \frac{r}{2r+3}\left(\frac{W a^2 b}{l^2} + \frac{W a b^2}{2 l^2}\right)$$

If the load is uniformly distributed along A B, then

$$H h = \frac{w l^2}{2}$$

$$P + P_1 = w l$$

Therefore

$$U = \int_0^l P^2 x^2 \frac{dx}{2EI} + \int_0^h \left(P l - \frac{w l^2}{2h} x\right)^2 \frac{dx}{2E I_0} + \int_0^l \left\{(w l - P) x - \frac{w x^2}{2}\right\}^2 \frac{dx}{2EI}$$

Thus we get

$$\frac{dU}{dP} = \frac{2}{3}\frac{P l^3}{I} + \frac{P l^3}{I_0} - \frac{\frac{w l^3}{2}}{2\frac{I_0}{h}} - \frac{5}{24}\frac{w l^3}{I} = 0$$

from which

$$\frac{2r+3}{r}\cdot P l = \frac{l^2}{}\left(\frac{3}{2r} + 1\right) + \frac{w l^2}{8}$$

or

$$P l = M_C = \frac{w l^2}{8}\left(2 + \frac{r}{2r+3}\right) = \frac{w l^2}{8}\left(\frac{5r+6}{2r+3}\right)$$

or

$$= \frac{1}{2} w l \cdot \frac{2}{l} + \frac{r}{2r+3}\left(\frac{w l^2}{12} + \frac{1}{2}\cdot\frac{w l^2}{12}\right)$$

$$= \text{Moment of load about A} + \frac{r N}{2r+3}$$

where again N is equal to

$$\frac{w l^2}{12} + \frac{1}{2}\frac{w l^2}{12}$$

CANTILEVER STRUCTURE OF THREE MEMBERS RIGIDLY CONNECTED AT B AND C AND FIXED AT A AND B, FIG. 10A, OR VERTICAL FRAME WITH LOAD ON THE VERTICAL POST, FIG. 11A.

There are couples acting at A and D and at B and C.

Let I be the moment of inertia of B C, and I_0 be the moment of inertia of A B.

Let

$$\frac{I}{l} \times \frac{h}{I_0} = r.$$

and let the couple at B in B C on the side of B toward C be M_{BC} and so on.

The total work done on the structure is:

$$U = \int_0^l \left\{M_{BC} - (M_{BC} - M_{CB})\frac{x}{l}\right\}^2 \frac{dx}{2EI} + \int_0^h \left\{M_{DC} - (M_{DC} - M_{CD})\frac{x}{l}\right\}^2 \frac{dx}{2E I_0} + \int_0^a \left\{M_{AB} - (M_{AB} - M_{BA})\frac{x}{l} - \frac{W b x}{l}\right\}^2 \frac{dx}{2EI} + \int_0^b \left\{M_{BA} - (M_{BA} - M_{AB})\frac{x}{l} - \frac{W a x}{l}\right\}^2 \frac{dx}{2E I_0}$$

Horizontal forces P, in Fig. 11*a*, act at A and D, the sum of which is equal to W. Equal and opposite vertical forces H act at the points A and D.

Taking moments about the points A:

$$H l - M_{DC} - W a = M_A = -M_{AB}.$$

Taking moments about B:

$$H l - M_{DC} - P h = M_{BA}$$

$$M_{DC} + P h = M_{CB}$$

From which

$$M_{BA} + M_{AB} - M_{CB} + M_{AB} - W a = 0$$

Substituting for any one of these in terms of the others there are three unknowns, and by differentiating with respect to each of these and equating to zero, three equations are obtained. Simultaneously solving these equations are:

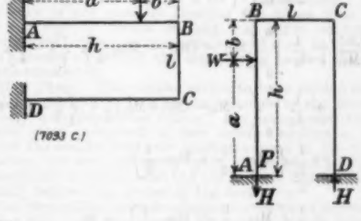
$$M_{AB} = W a \cdot \frac{3r+1}{2(6r+1)} - \frac{(3r+1)}{2(6r+1)}\cdot\frac{W a^2 b}{l^2} + \frac{3r^2 + 12r + 1}{2(6r+1)(r+2)}\cdot\frac{W a b^2}{l^2} \quad . \quad . \quad (1)$$

$$M_{DC} = W a \cdot \frac{3r+1}{2(6r+1)} - \frac{(3r+1)}{2(6r+1)}\cdot\frac{W a^2 b}{l^2} + \frac{3r^2 - 1}{2(6r+1)(r+2)}\cdot\frac{W a b^2}{l^2} \quad . \quad . \quad (2)$$

$$M_{CB} = W a \cdot \frac{3r}{2(6r+1)} - \frac{3r}{2(6r+1)}\cdot\frac{W a^2 b}{l^2} - \frac{r(5-3r)}{2(6r+1)(a+2)}\cdot\frac{W a b^2}{l^2} \quad . \quad . \quad (3)$$

$$M_{BA} = -W a \frac{3r}{2(6r+1)} + \frac{3r}{2(6r+1)}\cdot\frac{W a^2 b}{l^2} + \frac{r(q r+7)}{2(6r+1)(r+2)}\cdot\frac{W a b^2}{l^2} \quad . \quad . \quad (4)$$

When W acts at the end B of the column A B, a is equal to l and $b = 0$.



Then

$$M_{AB} = M_{DC} = \frac{W l}{2}\cdot\frac{3r+1}{6r+1}$$

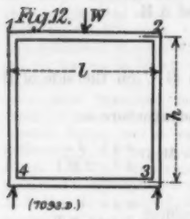
$$M_{CB} = M_{AB} = \frac{W l}{2}\cdot\frac{3r}{6r+1}$$

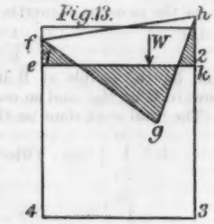
An interesting case may arise when due to earth pressure the load along A B may vary uniformly from zero at B to a maximum at A. Let W equal the total thrust on A B. Then the couples can be found at A, B, C and D by substituting $\frac{W h}{3}$ for W a, $\frac{W l}{15}$ for $\frac{W a^2 b}{l^2}$ and $\frac{W l}{10}$ for $\frac{W a b^2}{l^2}$.

When the load is w per foot run, uniformly

distributed along A B, substitute $\frac{w\,l^2}{2}$ for W a, $\frac{w\,l^2}{12}$ for $\frac{W\,a^2\,b}{l^2}$ and $\frac{w\,l^2}{12}$ for $\frac{W\,a\,b^2}{l^2}$.

A RIGID RECTANGLE 1 2 3 4 WITH A LOAD W AT ANY POINT ON THE BEAM 1 2 (FIG. 12 AND 13).





The moment of inertia of 12 = I
" " " 43 = I_2
" " " 14 = I_1
" " " 32 = I_3

$\frac{I_0}{l} \times \frac{h}{I_1} = r$, $\frac{I_0}{l} \times \frac{l}{I_2} = p$, $\frac{I_0}{l} \times \frac{h}{I_3} = q$

The bending moment at any point in 34

$$= M_{43} - (M_{43} - M_{34})\,\frac{x}{l}$$

where x is any distance from 4.

The bending moment at any point in 41

$$= M_{41} - (M_{41} - M_{14})\,\frac{x}{l}$$

where x is any distance from 4.

The bending moment in 32

$$= M_{32} - (M_{32} - M_{23})\,\frac{x}{l}$$

where x is any distance from 3.

The bending moment at any point between 1 and the load W

$$= M_{12} - (M_{12} - M_{21})\,\frac{x}{l} - W\,b\,\frac{x}{l}$$

where x is the distance from 1.

The bending moment at any point between 2 and the load W

$$= M_{21} - (M_{21} - M_{12})\,\frac{x}{l} - W\,a\,\frac{x}{l}$$

where x is the distance from 2.

Then the total work done by flexure is :

$$U = \frac{1}{2\,E\,I_1}\int_0^h \left\{M_{41} - (M_{41} - M_{14})\,\frac{x}{h}\right\}^2 dx + \frac{1}{2\,E\,I_3}\int_0^h \left\{M_{32} - (M_{32} - M_{23})\,\frac{x}{h}\right\}^2 dx + \frac{1}{2\,E\,I_2}\int_0^l \left\{-M_{41} - (M_{32} - M_{41})\,\frac{x}{l}\right\}^2 dx + \frac{1}{2\,E\,I_0}\int_0^a \left\{-M_{14} - (M_{23} - M_{14})\,\frac{x}{l} - W b\,\frac{x}{l}\right\}^2 dx + \frac{1}{2\,E\,I_0}\int_0^b \left\{-M_{23} - (M_{14} - M_{23})\,\frac{x}{l} - W a\,\frac{x}{l}\right\}^2 dx$$

$$E\,\frac{d\,U}{d\,M_{41}} = \frac{1}{I_1}\int_0^h \left\{M_{41} - (M_{41} - M_{14})\,\frac{x}{h}\right\}\left\{1 - \frac{x}{h}\right\} dx + \frac{1}{I_2}\int_0^l \left\{-M_{41} - (M_{32} - M_{41})\,\frac{x}{l}\right\}\left\{\frac{x}{l} - 1\right\} dx$$

$$= \frac{1}{I_1}\left\{M_{41}\cdot\frac{1}{3} + M_{14}\cdot\frac{1}{6}\right\} + \frac{1}{I_2}\left\{M_{41}\cdot\frac{1}{3} + M_{32}\cdot\frac{1}{6}\right\} = 0$$

from which

$$M_{41}\left(\frac{r}{3\,p} + \frac{1}{3}\right) + M_{14}\left(\frac{r}{6\,p}\right) + M_{32}\cdot\frac{1}{6} = 0 \quad (1)$$

$$E\,\frac{d\,U}{d\,M_{14}} = \frac{1}{I_1}\int_0^h \left\{M_{41} - (M_{41} - M_{14})\,\frac{x}{h}\right\}\left\{\frac{x}{h}\right\} dx + \frac{1}{I_0}\int_0^a \left\{-M_{14} - (M_{23} - M_{14})\,\frac{x}{l} - W b\,\frac{x}{l}\right\}\left\{\frac{x}{l} - 1\right\} dx + \frac{1}{I_0}\int_0^b \left\{-M_{23} - (M_{14} - M_{23})\,\frac{x}{l} - W a\,\frac{x}{l}\right\}\left\{-\frac{x}{l}\right\} dx$$

$$= \frac{1}{I_1}\left\{M_{41}\cdot\frac{1}{6} + M_{14}\cdot\frac{1}{3}\right\} + \frac{1}{I_0}\left\{M_{14}\left(\frac{a^2}{2\,l} - \frac{b^3}{5\,l^2} + \frac{b^2}{2\,l} - \frac{b^3}{3\,l^2}\right) + M_{23}\left(\frac{a^3}{3\,l^2} + b - \frac{b^2}{l} + \frac{b^3}{3\,l^2}\right) + w\left(\frac{b\,a^3}{3\,l^2} + \frac{a\,b^2}{2\,l} - \frac{a\,b^3}{3\,l^2}\right)\right\}$$

$$= \frac{1}{I_1}\left\{M_{41}\cdot\frac{h}{6} + M_{14}\cdot\frac{h}{3}\right\} + \frac{1}{I_0}\left\{M_{14}\cdot\frac{3\,a\,l^2 - 3\,a^2\,l + a^3 + b^3}{3\,l^2} + M_{23}\cdot\frac{3\,a^2\,l - 2\,a^3 + 3\,b^2\,l - 2\,b^3}{6\,l^2} + W\left(\frac{2\,a\,b^3 - 2\,a^3\,b + 3\,a^2\,b}{6\,l^2}\right)\right\}$$

$$= \frac{1}{I_1}\left\{M_{41} + 2\,M_{14}\right\} + \frac{1}{I_0}\left\{2\,M_{14} + M_{23} + N + N_1\right\} = 0$$

or

$$M_{41}\,r + M_{14}\,(2\,r + 2) + M_{23} + N + 2\,N_1 = 0 \quad (2)$$

where N = couple at end of fixed beam

$$= \frac{W\,a^2\,b}{l^2}$$

and

$$N_1 = \frac{W\,a\,b^2}{l^2}$$

$$\frac{E\,d\,U}{dM} = \frac{1}{I_3}\int_0^h \left\{M_{32} - (M_{32} - M_{23})\,\frac{x}{h}\right\}\left\{1 - \frac{x}{h}\right\} dx + \frac{1}{I_2}\int_0^l \left\{-M_{41} - (M_{32} - M_{41})\,\frac{x}{l}\right\}\left\{-\frac{x}{l}\right\} dx$$

$$= \frac{1}{I_3}\left\{M_{32}\cdot\frac{1}{3} + M_{23}\cdot\frac{1}{6}\right\} + \frac{1}{I_2}\left\{M_{41}\cdot\frac{1}{6} + M_{32}\cdot\frac{1}{3}\right\} = 0$$

$$= M_{41}\cdot\frac{1}{6} + M_{32}\left\{\frac{q}{3\,p} + \frac{1}{3}\right\} + M_{23}\cdot\frac{q}{6\,p} = 0$$

$$= \underline{M_{41}\cdot p + M_{32}\,(2\,q + 2\,p) + M_{23}\cdot q = 0} \quad (3)$$

$$\frac{d\,U}{d\,M_{32}} = \frac{1}{I_3}\int_0^h \left\{M_{32} - (M_{32} - M_{23})\,\frac{x}{h}\right\}\left\{\frac{x}{h}\right\} dx + \frac{1}{I_0}\int_0^a \left\{-M_{14} - (M_{23} - M_{14})\,\frac{x}{l} - \frac{w\,a\,x}{l}\right\}\left\{-\frac{x}{l}\right\} dx + \frac{1}{I_0}\int_0^b \left\{-M_{23} - (M_{14} - M_{23})\,\frac{x}{l} - \frac{w\,a\,x}{l}\right\}\left\{\frac{x}{l} - 1\right\} dx$$

$$= \frac{1}{I_3}\left\{M_{32}\cdot\frac{h}{6} + M_{23}\cdot\frac{h}{3}\right\} + \frac{1}{I_0}\left\{M_{14}\left(\frac{a^2}{2\,l} - \frac{b^3}{5\,l^2} + \frac{b^2}{2\,l} - \frac{b^3}{3\,l^2}\right) + M_{23}\left(\frac{a^3}{3\,l^2} + b - \frac{b^2}{l} + \frac{b^3}{3\,l^2}\right) + w\left(\frac{b\,a^3}{3\,l^2} + \frac{a\,b^2}{2\,l} - \frac{a\,b^3}{3\,l^2}\right)\right\}$$

$$= \frac{1}{I_3}\left\{M_{32} + 2\,M_{23}\right\} + \frac{1}{I_0}\left\{M_{14} + 2\,M_{23} + 2N + N_1\right\} = 0$$

$$= \underline{q\,M_{32} + M_{23}\,(2\,q + 2) + M_{14} + 2\,N + N_1 = 0} \quad (4)$$

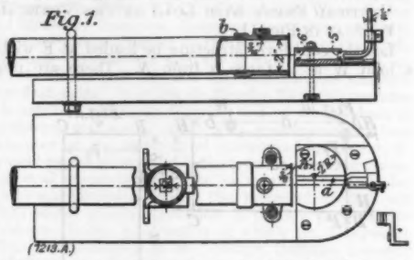
(To be continued.)

IMPACT LOSSES OF JETS.*

By J. G. BURNELL, B.E., A.M.Inst.C.E.

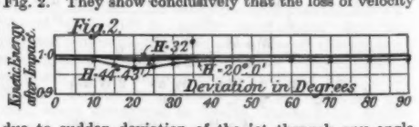
ANALYSES of the results of numerous tests of centrifugal pumps carried out by the author during the last ten years showed the inadequacy of the usual text-book exposition of the flow of water on to vanes. It is generally stated "that in all properly designed hydraulic machines such as centrifugal pumps and turbines, in which water flowing in a definite direction impinges on moving vanes, the relative velocity of the water and the vanes should be parallel to the direction of the vanes at the point of contact. If not, the water breaks into eddies as it moves on to the vanes and energy is lost." The common designs of centrifugal pump vanes, however, depart considerably from this principle. Information of help on this subject is contained in an article on Steam Turbines by H. M. Martin, in ENGINEERING of August 25, 1911. It is there stated that tests had shown that the losses in the buckets themselves of impulse steam turbine wheels are practically independent of the speed of the wheels, and, therefore, of the angle at which the steam strikes the buckets. Some experiments with water jets, carried out by Professor Donat Banki, and described in the *Zeitschrift des Vereines Deutscher Ingenieure* of September 11, 1911, are referred to as confirming this conclusion. Failing to secure a copy of Professor Banki's experiments, the following experiments were made by the author in order to secure definite information on this subject, obviously of the first importance in the design of water turbines and centrifugal pumps.

The tests were carried out at the pumping station of the State Rivers and Water Supply Commission of Victoria at Merbein (near Mildura) at a time when no pumping was in progress. Water can then be taken from the two 36-in. diameter rising mains and outlet basins under a head of about 60 ft. without any liability to fluctuations of pressure due to other draw off from the system. The apparatus employed is shown in Fig. 1. Water supplied through a 2-in. galvanised iron pipe discharges from a square orifice (0·75 in. square) and passes between two discs, which have a straight brass guide piece a clamped between them by a small bolt passing through the centres of the discs. By moving the



guide piece about this bolt, the jet is deflected through any desired angle. The guide piece, and consequently the distance between the discs, decreases in depth from 0·60 in. at entry to 0·50 in. at exit. The depth of 0·60 in. is just sufficient to admit the jet without it striking the edges of the discs. The guide piece, where it passes beyond the upper disc, is provided with a clamp which carries a small impact tube (*) used in conjunction with a mercury column for measuring the energy of the stream after deflection. The impact tube is formed of a short piece of ¼-in. diameter brass tube, bent to shape, the mouth being ground to an edge. The size of the contracted jet was so chosen (approximately 0·36 sq. in.) that the mouth of the tube would be fully covered by the section of the jet even when only half of the total flow was striking it. The upper disc is of plate glass, of 2-in. radius, and permits a clear view of the flow of the jet. The lower disc is of brass, graduated around its edge to show the angle at which the guide piece is set to the axis of the issuing jet. The orifice plate is soldered to a brass fitting b, bored out to 2 in. diameter, the 2-in. supply pipe being screwed up flush with this. At a point 1¼ in. in rear of the orifice a $\frac{5}{16}$ in. diameter hole is drilled into the casting b, and a short length of ¾-in. pipe screwed in above. To the top of this is screwed one end of a three-way indicator cock, the other end being connected to the impact tube by a short rubber tube. The centre leg of the cock is connected by rubber tubing to the mercury column. By manipulating the three-way cock the head behind the orifice and at the impact tube can be read on the mercury column. Special precautions had to be taken in the experiments at the lower heads to avoid error due to air being trapped in the rubber tube connections. In these experiments the mercury column was replaced by a length of ¾-in. diameter glass tubing in which the height of the water itself was noted. The rubber tube connections to this tube were as short and direct as possible, and throughout their length rose continuously to the tube, so that any air entering the system at once escaped. Without these precautions, steady and consistent readings cannot be obtained. The pressure and rate of flow were very steady throughout the tests.

The first set of experiments was designed to determine the loss of kinetic energy in the jet due to varying deviation. The pressure at the orifice was maintained approximately constant for each set of readings. All pressure readings are reduced to head in feet of water above the centre of the orifice. In the case of the head behind the orifice, the heads given in the second column include correction for velocity of approach in the 2-in. diameter pipe. These results are shown plotted in Fig. 2. They show conclusively that the loss of velocity



due to sudden deviation of the jet through any angle up to 90 deg. is practically negligible. The greatest loss of kinetic energy occurs between 20 deg. and 25 deg. deviation, and is of the order of 2 per cent. only. It was observed, however, that for angles of deviation of 10 deg. and upwards, a certain portion of the total flow took place along the vane in the direction opposite to the main flow. It was necessary then to determine the extent of this back flow for various angles of deflection of the jet. To do this the main deflected stream was led into a barrel by means of a length of spouting, and the head at the orifice and the time taken to fill the barrel were noted. For each set of readings the head at the orifice was maintained approximately constant. Results are plotted in Fig. 3. The figures utilised were obtained by correcting the discharge to a common head for each set. Obviously for these experiments the volume of the barrel need not be known, provided only it be constant. It was, however, carefully checked up for another reason. Knowing this volume and the coefficient of discharge for the orifice —0·64 approximately (see Gaskell, P.I.C.E. 1914), the

* Abstract of paper read before the Melbourne Division of the Institution of Engineers, Australia, October 26, 1921.

* For much practical information on the construction and use of the impact tube, see article by S. A. Moss, Journal American Society M.E., 1916, vol. 38.

time necessary to fill the barrel, with a given head at the orifice, can be calculated. These calculated times are then helpful as checks to the time necessary to fill the barrel at zero deviation. Such a check on the observation is desirable, since a stop watch was not available at the time, and an error of one second in the time observed for filling the barrel is possible.

The three curves of Fig. 3, in which the proportion of back flow is plotted against the deviation of the jet in degrees, show a curious inflexion extending from 15 deg. to 30 deg. Such an inflexion might be suspected as due to experimental error were it not very similar in all three curves, and did it not correspond almost exactly to an inflexion in the curves purposely shown below, in which the kinetic energy after impact or deflection is similarly plotted against the deflection of the jet in degrees.

Before leaving this subject it will be well to consider briefly the conditions of equilibrium in the region where the jet strikes the vane. Referring to Fig. 4, consider a jet flowing with uniform velocity v, corresponding to a head h, striking upon a vane as shown.* The main flow shoots to the right, while a smaller portion doubles back to the left. Along the free boundaries of the jet the pressure must, of course, remain atmospheric, and the velocity will be v, since there is no gain nor loss of energy.

There will be some stream line $q\ p$ which will turn neither to the right nor to the left until it meets the vane at the point p. Obviously at this point the velocity will be reduced to zero, and the pressure will correspond to a head of h feet. To either side of this line $q\ p$ the stream lines will turn left and right along the vane. The nearer a stream line runs to point p the lower will be its velocity and the higher its pressure at this point. The loss of kinetic energy in the jet at deflection must be somewhat akin to the loss of kinetic energy resulting from flow in a passage successively diverging and converging. From the very small measured loss of kinetic energy it appears that the losses due to gradual expansion and contraction of a jet when the stream lines are free to take their own path (as in this case) are much smaller than the corresponding losses when the stream lines are confined by straight taper or trumpet-shaped tubes of the most favourable form.

The relative proportion of back flow to forward flow is evidently such that—

$$\int_{l=o}^{l=b\ p} \frac{u^2}{r}\,dl = \int_{l=o}^{l=c\ p} \frac{u^2}{r}\,dl = h\ g$$

where u = velocity at any point.
r = radius of curvature of path at same point.
l = distance of this point from b or c measured along $b\ p$ or $c\ p$.

Stream lines will be approximately asymptotic to the line $q\ p$ and the face of the vane.

Since working up the results of the foregoing tests the author found that Professor A. H. Gibson has published a simple rational solution (†) to determine the relative proportions of the streams escaping from each end of the vane in the case of oblique impact of a jet on a stationary plane surface provided with flanges to prevent the stream spreading sideways. The sectional area of each of these streams can be calculated as follows by expressing the fact that the change of momentum parallel to the plate is unchanged by impact if friction be neglected. Suppose the jet be of unit width and of area t, the thickness of the discharge streams being t_1 and t_2 and let θ be the (acute) angle between the direction of the jet and the plane, v the velocity of the jet, and w the weight of unit volume of the fluid, then initial momentum parallel to plane

$$= \frac{w\ t\ v^2}{g} \cos\theta$$

and final momentum parallel to plane $= \frac{w\ v^2}{g}(t_2 - t_1)$

$$\therefore\ t\cos\theta = t_2 - t_1$$

But $t = t_2 + t_1$

$$\therefore\ \frac{t_1}{t_2} = \frac{1 - \cos\theta}{1 + \cos\theta}\ \ i.e.,\ t_2 > t_1$$

$$\text{Also}\quad t_1 = t\left(\frac{1 - \cos\theta}{2}\right) \qquad \text{——(a)}$$

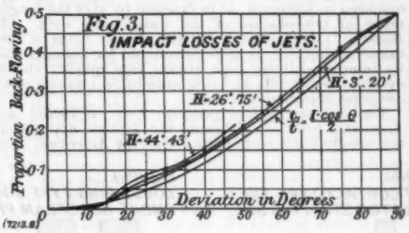
$$\text{and}\quad t_2 = t\left(\frac{1 + \cos\theta}{2}\right)$$

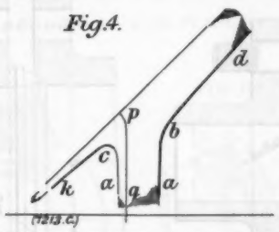
Let us now compare the results given by equation (a) above with the author's experimental results for the proportion of back flow. In Fig. 3 has been plotted the curve corresponding to the equation $\frac{t_1}{t} = \frac{1 - \cos\theta}{2}$.

It will be seen at once that while the experimental results do not fall exactly on this curve they do follow it more or less closely, and conform generally to the law it expresses. From 0 deg. to 10 deg. there is considerably less back flow than indicated by the theory: exact agreement occurs about 15 deg., beyond which the back flow is always greater than indicated by the theory. Above 15 deg. the discrepancy is greater the greater the head. In practice, however, the results between 0 deg. and 15 deg. are those of greatest importance. The proportion of back flow up to 10 deg. deflection is so very small — about one part in 1,000 — as to be quite negligible in ordinary practice. For 15 deg. it may be taken as 1·8 per cent.

Friction Losses in Bends.—Closely related to the subject of the loss by impact is that of the losses in flow round bends. The apparatus already described appeared easily adaptable for experiments on this subject. A strip of sheet brass, tapering in width from 0·60 in. to 0·50 in., was carefully bent to form a 90 deg. bend of internal radius 1¾ in., and was mounted between the two discs so that the water from the orifice flowed on to the wider end almost tangentially. The impact tube was arranged to measure the energy of the stream after passing around the bend.

For each observation the flow was adjusted to that desired, and then by manipulating the three-way cock corresponding readings of the head at the orifice and at the impact tube were taken on the mercury column. The results show that for the bend used the loss of energy in flowing round the bend was small beyond the error of observation. It is interesting to compare this result with the results of some very careful experiments "On the Loss of Pressure in Water flowing through Straight and Curved Pipes," carried out by Dr. Brightmore.* Using bends of various radii with various velocities, it was found in these experiments that while the loss of head due to the bend was approximately $\frac{1}{3}\frac{V^2}{2g}$ such loss took place entirely in the length of pipe following the bend, and not in the bend itself. Measurements of the loss of head in the bends themselves failed to show any greater losses than those due to the normal resistance in a straight pipe equal in length to the bend. Analyses of careful tests of centrifugal pumps had previously indicated that the internal losses in the passages of a pump rotor do not exceed $\frac{1}{3}\frac{V^2}{2g}$, V being the average velocity in the passages. The results of these experiments point to the probability of their being even less than this in good designs.





The author desires to acknowledge the assistance rendered by Mr. J. R. Kemp in preparing the apparatus and carrying out the tests.

BRITISH AND AMERICAN LOCOMOTIVE DESIGN AND PRACTICE.

British and American Locomotive Design and Practice. Some Comparative Comments thereon from Practical Experience.†

By P. C. DEWHURST, Locomotive Carriage and Wagon Superintendent, Jamaica Government Railways, Member.

(*Concluded from page* 377.)

Superheaters.—The American-Schmidt pattern is now standard in America, this type being identical with the Schmidt, except that metal-to-metal spherical-cone joints, Fig. 10 (*d*) (page 406), are employed in connecting the units to the header instead of the ring joints as generally used in British locomotives. The author has a very high opinion of these joints, based on experience with them under the same particularly trying conditions as mentioned elsewhere. He is unable to see why the old ring-type joint with asbestos jointing is continued in British practice, and for the same reason he does not see any necessity for the method of fastening the unit tubes into the header by expanding them, as in some systems of fastening; this method appears rather an arduous one to accomplish a simple result.

There are practically no special arrangements of headers and units in use in America similar to the designs emanating from Swindon, Doncaster and Eastleigh, &c., in England. There were a number of designs of smoke-box type superheaters in use in America similar in many respects to various designs in use in England prior to the general adoption of the smoke-tube type, but these have all disappeared in a similar manner to the British patterns and no further reference to them is needed.

Regarding dampers to stop the draught through the superheater flues when steam is shut off, the author's experience with engines operating where up grades of 1 in 30 change at once to down grades of similar severity, dampers working automatically on the opening and closing of the regulator are essential owing to the heavy fire which it is necessary to maintain to the top of the grade being altogether too fierce to be allowed access to the unfilled units whilst drifting; the down grades are too steep to allow a small amount of steam to be circulated through. He has not tried a system of automatic air inlets in the superheater circuit, but is averse to it on account of the very large amount of superheated air which he considers would be drawn through the cylinders on long downhill sections, and which would seem likely to cause lubrication troubles.

Smoke Boxes.—The difference between the simple interior of the usual British smoke-box and the American with its deflectors and spark arresters, is principally due to the grades of coal used, although the law in various parts of the United States of America, being more stringent than British, no doubt has its effect also. With reasonable-sized smoke boxes, as in present-day British practice, which give a more steady vacuum than the old small patterns, coupled with the class of coal burned, there appears to be sufficient provision without elaborate fittings inside.

Where the major portion of the fuel burnt is small (or soft) coal, which even after wetting is liable to be lifted off the fire by the blast when engines are working heavily, more elaborate arrangements are needed, and in consequence one finds deflectors or diaphragm plates, dead plates and spark-arrester netting. The diaphragm plate is considered by the author to be a good feature, as it ensures a proper proportion of draught through the lower tubes, and in conjunction with the netting causes the products of combustion to traverse the lower part of the smoke-box towards the front and through the netting, before escaping to the atmosphere; this circulation ensures that any incandescent particles larger than the netting shall be thoroughly "teased" until they are small enough to pass, by which time they have become dead and harmless. Undoubtedly in the case of locomotives built for Colonial use—especially tropical lines where fires of enormous extent are very easily started—smoke boxes need to have fittings similar to, or a modification of, the American system and in particular to have ample length. The space between the diaphragm plate and the tube plate is made use of by means of a damper at the lower part (operated automatically by the admission, or otherwise, of steam from the regulator) to isolate the tubes containing the superheater units.

American practice in respect to smoke-box fronts and doors, also differs fundamentally from the British; the fronts are always made easily detachable, being bolted on, are generally of pressed or cast steel, very often of cast-iron and the door, which is also of cast-iron, is always made very much smaller in proportion to the diameter of the smoke-box than in British practice, usually about half to three-fifths the diameter of the smoke box.

The experience of the author is entirely in favour of the American pattern, the smaller door having its lower edge well away from the bottom of the smoke-box, does not suffer from warping and burning away due to drawing air, as frequently happens with British pattern smoke-boxes when engines are worked heavily. That this is not due simply to the larger volume of the American smoke-box is proved by the case of a set of engines under the author's control, which gave endless trouble with the usual British pattern of door, carefully faced at the joint, but which was entirely cured by substituting simple cast iron smoke-box fronts with cast-iron doors about two-thirds the diameter of the original doors, and without any special facing. Clips had been used round the original doors and were of course, applied to the American pattern doors also, as is always done.

It is clear that the small door, together with the diaphragm plate and other fittings inside the smoke-box, prevents the tubes all being properly cleaned out from the smoke-box end without a lot of dismantling; this difficulty is got over by cleaning the tubes from the fire-box end by means of long thin pipes conveying compressed air (sometimes steam) and used as cleaners and blowers combined, the ashes being carried through to the smoke-box.

Blast Pipes.—This matter seems to have settled down in American design in a similar manner to the British, namely, a single circular orifice. For many years double nozzle pipes composed of two circular orifices in line across the smoke-box were much favoured in American practice, but are now rarely used. High blast pipes are entirely out of favour, and the top is never higher than—usually below—the centre of the tube area.

One recent American development consists of a circular orifice, but with four partial bridges projecting into it, and it is claimed to give better results than a plain circular orifice of an area equal to that of the special type, less its bridges; if this is so, and a considerable number of tests go to prove it, it is evidently due to the roughening of the outside of the exhaust cone and consequently its "pull." It would be interesting to see this type of blast pipe tried on express work in England. The various forms of blast pipe adjustable orifices sometimes used in British practice find no favour in America. "Petticoat" pipes are, however, extensively used and project downwards usually rather more than in British locomotives.

Smoke-Box Steam Pipes.—Cast-iron pipes are universal in American practice and last practically for ever, and no coppersmiths' work is involved; on the other hand, they are heavier (where weight is undesirable), and their extra thickness may obstruct the withdrawal of a few tubes. In some cases of older types of engines with the steam

* In the discussion it was pointed out that line $q\ p$ must impinge normally on the vane at p, to do which it must curve in region of vane.

† *Hydraulics and its Applications*, by A. H. Gibson, page 368.

* Proc.Inst.C.E., 1907, vol. clxix.

† Paper read before the Institution of Mechanical Engineers on Friday, March 17, 1922.

ways in the saddle casting, their position made the expansion of certain tubes a difficult matter; the joints are in all cases ground joints with the usual rings, as referred to later; these joints are very effective and there is no reason why they should not be used with copper steam pipes, and the solution of this question appears to be to use copper pipes combined with the joints mentioned.

Smoke-Box Fastening.—The old British method of bolting the smoke-box to lips on the cylinder casting front and back and riveting to the frame at each side, allows too much scope for air leaks and eventual "working" in the rivets, &c. The "Saddle" type certainly necessitates care in locating the position of the bolt holes to enable boilers to be interchanged, but not more care than should be—but often is not—used in setting out the holes in the old square-set type.

The saddle type of smoke-box being circular calls for the use of the drumhead tube plate, and in American practice this is always placed inside the front ring of the boiler barrel; mention is made of this fact as it is not essential for drumhead tube plates to be placed inside, and in some cases in British practice they are considerably larger than the diameter of the front ring of the boiler; as this is an advantage in giving more opportunity for "breathing" of the plate between the outer row of tubes and the boiler barrel, the author considers it preferable. He favours the saddle type of smoke-box base, both in connection with plate and bar framing, as providing the most substantial fastening and being simpler to make and keep airtight.

Cabs.—It is recognised in British practice nowadays that an adequate cab, more or less of the American style, is needed. A roomy cab is an advantage and the author considers particularly that it should be the full width of the foot plate, thus allowing for doors on each side leading on to the running plate without the necessity of going round the side of the cab. The exception to this is with the 4-4-0, and in some cases the 4-6-0 type, with large coupled wheels which preclude this arrangement. Where locomotives are built for use in hot climates it is essential that the cab be as high and roomy as the loading gauge will permit, and with ventilators in the roof.

Regarding seats for the enginemen, these are an advantage where the runs are long but at slow speeds with a good number of stops; they should, however, not be so comfortable as to induce the driver to remain sitting at every stop, where opportunity occurs for him to be better employed looking round his engine.

In one respect the British cab has, until recent years, been superior, that is, in being constructed of iron or steel. All modern American cabs are, of course, of similar material, but the standard practice until well into the present century was to employ wood; this, in the experience of the author, and, as may be expected, gave poor results.

Boiler Mountings in Cab.—The usual American method of attaching water gauge and other small boiler mountings on the fire-box front (or back-head plate) is not very substantial, it being customary to fix the ends of the gauge frames and other valves with a simple screw-shank connection having a taper thread, and to screw the fitting bodily in until a tight fit is obtained at the correct alignment. This appearance of weakness is particularly noticeable in the case of gauge fittings having no direct attachment to the boiler at the top of the gauge glass, connection to the boiler being obtained by a copper pipe leading from the top of the gauge glass to an entrance on top of the fire-box shell, such fittings giving the impression of being liable to fracture at the root of the thread if roughly handled. Another poor feature is the general use of screw cocks, taking some time to shut off, instead of a type of plug cock shutting off by a quarter turn.

The method of making the upper connection of the water gauge through the top plate of the fire-box casing is an excellent arrangement—the entrance should be made some distance from the back end of the boiler—being less liable to indicate incorrect water-level, due to surging in long boilers, when starting and fluctuating in speed on steep gradients. It must be said in connection with this question that American enginemen trust a good deal more to the three try-cocks placed conveniently to their hand, than to the gauge glass; this may be from experience of its defects as applied there.

On the other hand, the system, universal in America, of mounting a steam turret or "fountain," as it is called, on top of the fire-box within the cab, having one large dry pipe leading thence from the dome, cannot be equalled by any other method. This steam turret eliminates all other steam-taking joints on the boiler; it is a brass casting and the body is made sufficiently large to take further steam fittings if at any time needed, so that it is merely a matter of drilling and tapping an extra hole and fitting a steam cock thereto. The latter is a minor job, as there is always one main centre stop valve which shuts off steam from the entire turret, enabling any valve to be re-ground or attended to whilst the engine is in steam.

Injectors.—The author's experience is altogether in favour of the American form of injector, namely, the self-acting and restarting pattern of the "lifting" type. Its pull-out operating handle makes it much easier to "catch" the water than is the case with the British screw cock, and further with the American injector the water valve may be shut off to about 50 per cent. after the injector has started to deliver, and thus more control over the rate of feed to the boiler may be obtained. Although it would seem that the under or "drowned" type of injector should give best results with moderately hot water, yet the self-acting restarting lifting type has been so perfected, as in practice to give the longest range of temperature of the water dealt with. The British "Combination" pattern, whilst being a very excellent injector, is quite unsuitable for Colonial use; its internal delivery pipe always gets quickly choked up and the difficulty and time entailed in cleaning it out are great objections to its use.

Top delivery is now common both in British and American practice, although the British applications are usually much more refined than the American. Top feeds are an advantage, irrespective of any device for collecting deposit; in any event much of it will be converted into fine powder, which can be washed out. Whilst internal delivery pipes are most troublesome to keep clean, and side delivery arrangements become choked up just in the orifice into the boiler (due to its being the point where the delivery water meets the higher temperature water in the boiler), a top delivery obviates this and does not become foul even when very unsuitable water has to be used.

Safety Valves.—The Ramsbottom type was, until recently, almost exclusively used in British practice, but latterly various types of direct-loaded valves have been adopted. In America the use of two independent valves of directly-loaded "Pop" type has been the common practice from about 1866. Undoubtedly the Ramsbottom pattern is the most safe on account of its usual method of adjustment not allowing unauthorised persons to increase the pressure without an amount of work bound to draw attention, and on account of its construction allowing the enginemen to prove its action under steam without interfering with its setting. The directly-loaded patterns, however, can be adjusted with facility and accuracy under steam by the repair staff; they furthermore give, in the case of most makes of "Pop" type, a far less margin between the commencing blow-off pressure, the maximum, and the shut-down pressure. In the case of the Ramsbottom valve this is sometimes as much as 8 lb. per square inch, but with the "Pop" valves usually 5 lb., sometimes only 3 lb.; most of the "Pop" types are very efficient in this respect and in the discharge capacity.

The position of the safety valves in British practice is now almost exclusively over the fire-box, whilst American practice generally places it on the dome. The author considers the proper position is over the fire-box and apart from the dome; clearly it should be located nearest to the place of greatest ebullition, and it should not be near the regulator entrance for obvious reasons. On the other hand it should not be placed low down on the fire-box, as in that position a considerably larger amount of water will be lost from the boiler for a given release of pressure, than if situated on a subsidiary dome or other mounting of medium height. It should be noted, however, that in American practice the dome itself is usually fairly near the fire-box—this position of the dome being incorrect for reasons given in connection therewith in a previous section of the paper—and possibly the desire is to avoid further holes in the boiler shell.

Piping.—This is often rather scamped in American practice; on different engines built to the same specification the piping will sometimes be found to vary appreciably, and in the matter of brackets there is considerably less care than in British practice, and they are commonly fixed in different places. Clips are generally poor, being of a plain bent iron one-bolt pattern fixed by a bolt and nut without either check nut or split-pin; there are quite a number of these clips around the engine, especially under the running plate, and they frequently come loose in service and drop off.

Joints.—Copper ring joints in dome and other major boiler joints, also plain ground cone joints for regulator-rod stuffing boxes, as used in American practice, are very effective and far superior to asbestos or other similar jointing material as used with flat joints in British practice. They require no cleaning off and are much less expensive, as the copper rings can be re-used indefinitely by softening each time, and the cone joints only need regrinding. Further, the American method of using plain metal-to-metal joints, ground together, either of the flat and spherical surface loose-ring type, or of the spherical-cone direct-contact type, for all steam pipe and superheater unit joints, is also far superior to the asbestos and special copper and asbestos joints commonly used in British practice. Such metal-to-metal joints require, if anything, less attention when under repair, seldom needing to be re-ground to any extent, and they have the great advantage that when fitted up and once tested and found satisfactory, they never develop leaks whilst in service or, in fact, need to be disturbed until the engine returns again to shops. Fig. 10 (*a*) illustrates the copper-ring joint, (*b*) the direct-contact cone joint, (*c*) the loose-ring type, and (*d*) the direct-contact spherical and cone type as used with superheater units.

Fig. 10(a). COPPER-RING JOINT, STEAM CHEST COVER.

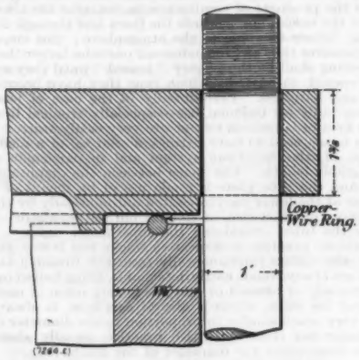


Fig. 10(b). DIRECT CONTACT TYPE JOINT. REGULATOR STUFFING BOX.

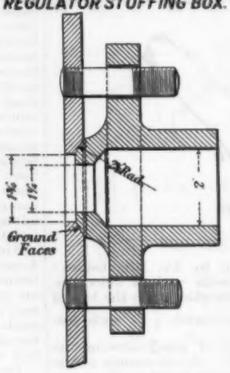


Fig. 10(c). LOOSE-RING TYPE JOINT. SMOKE-BOX STEAM PIPE.

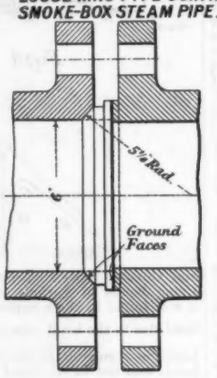
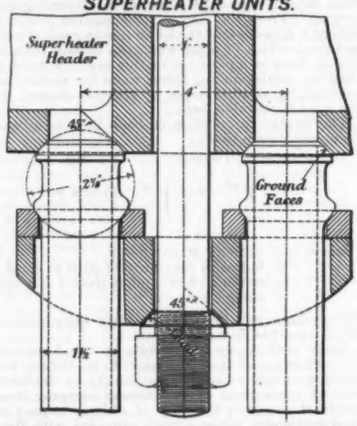


Fig. 10(d). CONE-SPHERE JOINT. SUPERHEATER UNITS.



Reversing Gear.—Steam reversing gear is practically always fitted to American locomotives of any appreciable size now, but for many years the old plain lever was retained on even the largest engines, until, finally, the duty became so heavy that power operated arrangements were adopted. It is remarkable that the screw reversing gear as employed in British practice for so many years was not commonly used, except on the Pennsylvania Railway from about 1914. Observations show that drivers of engines with lever reversing gear do not follow and take advantage of the variations of gradient, &c., as on engines equipped with screw gears (and, of course, those with power reverse gears).

The amount of fuel lost by the retention of the lever on practically all American locomotives during the forty years 1870–1910 must have been enormous, and even now comparatively heavy engines in American practice—and also most goods engines in British practice—are built with the old lever. There seems little gained by using close notches as in American practice, as it is not so easy for a driver to select the position desired when there are many small notches and a catch with a number of teeth, as with a lesser number of notches and a single catch. For shunting, a lever is perhaps preferable for quickness, but even pick-up goods train engines doing much shunting on the journey would be better if equipped with a combined screw and lever—quite a simple matter to design. It is not necessary for reversing screws to be so slow-operating as they are commonly made, a good deal of the work to be done by them is often due to insufficient balancing of the motion.

Regarding the usual American method of balancing the reversing shaft by springs, as against the most common British method of using weights, there is no doubt that when weight is a consideration springs are preferable, but otherwise plain weights, applied as nearly opposite the link hangers as possible, seem the better.

The system of balance much used in America, namely, a semi-elliptic spring placed on its side athwart the engine, and coupled to a lever in the centre of the reversing shaft—sometimes weighing about half that necessary to balance by dead-weight—is not altogether satisfactory, being apt to give different resistances at different states of camber; it is also applied in a bad position. The other American pattern with coiled springs, under compression, in cases, acting in line (or nearly so) with the link carriers is the best spring arrangement; if the spring should break, the case, by holding the parts in position, prevents much alteration in the resistance, they are also readily adjusted by means

of a nut and check-nut to give the exact balance required.

Bridle or reach rods from the reversing lever (or screw) to the reversing shaft are often, in American practice, made of tubing screwed at each end and fitted with the usual fork ends; this is not merely a question of cheapness, as is sometimes supposed, but weight for weight a tubular rod is much stiffer and does not "whip" like the usual style, whilst the threaded ends with a check-nut provide ready means for minor adjustments in the length of the rod.

Valve Gear, Motions.—The practically universal adoption of Walschaert valve gear in America is not surprising in view of all cylinders being outside, for which that gear is so well adapted; it is, in fact, rather surprising considering the number of years that valves on top of the outside cylinders have been in vogue, that inside valve gear necessitating rocking levers, intermediate transmission bars, and sometimes indirect motion, was not superseded long before it was. The author has known it stated that one of the reasons for the conversion was due to the abnormal weight of the eccentric straps of the large engines being developed at that time, causing trouble from overheating—to what extent this may have influenced the matter he is unable to say—he believes it was not customary in American practice to use anti-friction liners in eccentric straps, the cast-iron strap running bare on the eccentric, similar to the practice on certain British railways for goods engines, but often being of heavy and clumsy design—a few of the later link-motion engines of heavy type were provided with brass eccentric straps, thus reverting to very early British practice.

Mention should be made of a practice which had a considerable vogue in America at one time, that of using solid eccentric sheaves, in some cases cast on, and in others made solid, bored to fit the (parallel) axles and fitted before the wheels were applied. Sheaves cast-on or solid with the axle were also tried by Mr. S. W. Johnson on the Midland Railway for a few years in the "'Eighties." The practice is understood to have been discontinued on account of importing too much stiffness to the crank axle. In the case of the American pattern straight axles this trouble of course did not arise. The author, from experience, has nothing good to say about the solid sheaves, which eventually become slack and then nothing can be done to make a satisfactory job except to remove the solid sheave and fit one of the usual pattern.

A noteworthy point about the link-motion, as applied in American practice, was its frequently complicated arrangement, namely, transmission bars sometimes with bends or loops in them, and almost always with side sets, eccentric rods with bends and very severe sets and often of short lengths. The motion pins also were generally of much less diameter than in British practice, and being "stepped," that is, not of one diameter throughout and secured by a nut on one side, were liable to loosen the nut and work out when they had developed any slackness in the rod. The old form of built-up link was not, in the author's opinion, very reliable either. Even until recently with the Walschaert gear the links were often made unnecessarily heavy and complicated by means of large side plates to carry the trunnions.

Distribution Valves.—In respect to the past practice in slide valves, the American system of using large balanced valves—which the outside position on top of the cylinders made possible—was a great advantage over the British method of smaller shallow unbalanced valves; the freedom with which the steam got to and from its work, in spite of the longer distance to be travelled, had undoubtedly a great deal to do with the "freedom" which was noticed in comparison with British-built locomotives in newly-developed countries, which practically offset the advantage the British-built engine generally had in coal consumption, due to the more careful design of ash pan, fire door and boiler.

The balancing of the valves, which became customary from about 1880, was a complete success in eliminating wear, ports and valves being practically untouched time after time when engines were shopped; the valves were of cast-iron and often lasted as long as the cylinder casting, and the frequent periodical examinations for wear necessary with the British pattern of unbalanced bronze valves were not required.

The practice of the two countries in respect to piston valves differs little, if at all, one very good feature of American practice being the use of combined steam-chest covers and valve-spindle guides; these are cast in one piece; the slides, being disposed symmetrically about the centre line, are simple to machine and automatically ensure correct alignment on erection. The author considers these superior to any system of independently attached guides.

Pistons.—Piston heads do not differ much in either country, the usual single-plate pattern now being practically universal. In American practice more attention is given to lightening the heads, rolled and cast steel being used for this purpose; this is a great improvement on the practice there a few years back of employing double walled hollow piston heads of cast-iron, some cast in one piece and others built up in a fashion very conducive to failures on the line due to small parts working loose.

Piston tail rods are not commonly used in American practice, and where these are used they are for pistons 27 in. diameter and upwards, as against the British practice of applying tail rods to pistons over 19 in. or 19½ in. diameter; nor are supporting springs inserted in the piston head to confine the wear caused by its weight to the rings instead of the head itself.

One very good point in up-to-date American practice is the provision of sufficient length of piston rod to allow the piston to be taken out of the cylinder far enough to enable examinations to be made and new rings fitted, without breaking the cross-head fit.

A poor feature of American practice is that of riveting over the thread at the end of piston-head nuts after tightening, and using no other security. Also tapered ends of piston rods are frequently of considerably less diameter than the plain part of the rod, even at the cross-head end where the reduction of section caused by the cotter hole has to be provided for. This seems a mistake, as if the ends are of sufficient section, the body of a normal length rod must be unnecessarily heavy even allowing for re-grinding. The British practice of enlarging the ends is undoubtedly the correct one; hollow rods, in which the hole in the plain portion is larger than those in the ends are, of course, not referred to.

Crossheads and Slide Bars.—Present-day comparisons show little difference in these parts. In British practice, with inside cylinders the old four-bar type is still generally favoured, being very well suited for 0-6-0 and 0-8-0 inside cylinder engines where the distance between the cylinder centre lines and the leading axle is limited. In respect to outside cylinders both countries appear settled to the two-bar or "alligator" pattern. There is one type, however, sometimes used in each country, especially with outside cylinders, namely, the "Laird" with two bars above the piston rods; this is particularly referred to, as it is the one with its wearing surfaces furthest away from the dust of the line, and it has the advantage of presenting no horizontal surface for the dust and grit to settle on; it is a very good type for new and loose tracks.

Connecting Rods.—Comparing the types of big ends generally used, it is noticeable that American practice usually favours the old "strap" type, similar to those commonly used on inside-cylinder engines; whilst this is no doubt cheaper in first cost, it is more troublesome to maintain than the open-end or closed-end rods generally used with outside cylinders on British engines. The large mass of metal in the strap type is concentrated in an unfavourable position, such weight being preferably beyond the big-end centre, not between the two centres of the rod. In certain cases, however, where small diameter driving wheels are combined with a long piston stroke, open-ended big ends cannot be used owing to the chances of the filling block bolt striking obstructions on the ballast, at level crossings, &c. No comment is made regarding little ends, the usual types being common to both countries.

Coupling Rods, Crank Pins and Bushes.—Coupling rod pins on American locomotives are usually larger in diameter, but less in length, than British and the same thing applies to the knuckle joints and pins, also to the section of the rods themselves, which are seldom of the usual British I-section on engines with more than six-coupled wheels. This practice enables very large cylinders to be placed, driving outside the coupling rods, but still keeping within the required limits of width. Although the author finds that the shortness of the pins leads to a rather short life for the knuckle joints particularly, yet such rods allow much greater lateral flexibility than the British practice, and on severely curved lines the American practice gives less coupling-rod breakages and overheating of bushes. As mentioned in reference to frames, it is a disadvantage to have a coupling-rod section giving too much lateral stiffness compared to the engine frames—this being more likely to occur in connection with plate frames. It is possible, with a much-cut-out plate frame, together with coupling-rods of excessive stiffness, to have a locomotive "running on its 'rods.'"

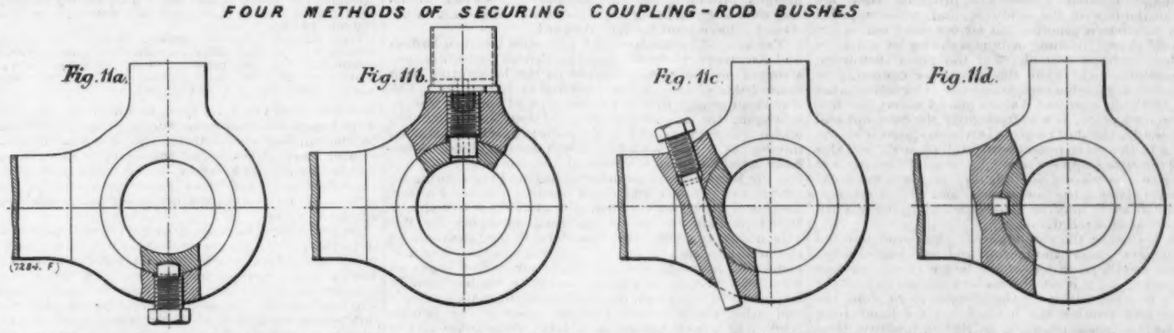
The methods of securing coupling rod bushes in America are by means of a set-screw underneath—Fig. 11 (*a*) or by a combined set screw and oil cup fastening—Fig. 11 (*b*); Fig. 11 (*a*) is also sometimes used on British locomotives as well as Fig. 11 (*c*) and (*d*). The author's experience is that with heavy duty only type (*d*) is satisfactory. If a bush is inclined to move, it generally causes the under set-screw to slack off and fall out; the same thing applies to the combination oil-cup fastening and set screw at top, except that the results are worse, and the tendency to slack out the set screw is aggravated by the motion of the rods helping to throw the oil cup off them. In fact he knows of no method of fastening so unsatisfactory and troublesome as this; the side-pin fastening is certainly better than either of the above, but is not such a definite fixing as is desirable.

Failure of the first three types allows the bush to turn the oil hole out of register, stopping the oil supply in addition to the trouble of the loose bush, and possibly causing a delay, whilst the latter arrangement of a key and keyway not only prevents the initial movement towards slackness, but in any event does not allow the bush to turn, and so prevents any delay.

Wheels and Tyres.—There is not now much variation in the practice of the two countries in respect to locomotive wheel centres; cast steel is always employed, with a few exceptions, in goods and shunting engines in each country where cast-iron is used. Up to long after the time when cast steel came into favour in British practice, cast-iron continued in use in American practice, having been employed for very many years; comparatively few wrought-iron wheels were made during the long period through which such wheels were so successful in England.

The general standard American practice has been for tyres to be secured by shrinkage only and with a lip about ½ in. by ¼ in. provided on the outside of the tyre; the shrinkage allowance being approximately $\frac{1}{750}$ of the diameter—about 50 per cent. greater than in British practice—and the author has many engines so running on lines with curves up to 3·6 chains radius and long gradients of 1 in 30, on descending which, the continuous brake-block pressure often heats the tyres till the paint begins to blister.

FOUR METHODS OF SECURING COUPLING-ROD BUSHES



On recent American locomotives, however (mostly passenger engines) tyres of 5 ft. 6 in. in diameter and over are now being provided with security rings of the Mansell and other types, or with lock-lips on the tyre itself. The author's experience is that the majority of broken tyres are fractured through the holes of the set-screw fastening, and as these holes inevitably weaken the tyre, he prefers a system of outside lock-lip and inside check ring when such security is necessary.

Lubrication.—American railways use a heavier bodied oil than British, generally speaking, and mostly depend on saturated elastic packing, as it is termed—composed of cotton and wool waste with a small proportion of horse hair, then saturated and drained—in the keeps or cellars of the axle boxes; auxiliary oil boxes, &c., are never used either for the journal bearings themselves or for the horn slides, some strands of the elastic packing worsted, leading from the small well of oil in the axle-box top to two holes running into the journal oil groove, and a few other strands leading to the rubbing faces of the box, being the usual method.

Slide bars, motion, rods, &c., are lubricated similarly to British practice, but controlled by adjustable needle valves instead of trimmings, although considerable use is now made of grease for connecting and coupling rods, being placed in the ordinary oil cups (but with the stems removed) and caused to work its way into the bearings, partly by initial pressure applied by means of a long plug cap substituted for the ordinary cap, and partly by the heat generated by the bearings themselves. A great many American built engines are now running, in which the axle boxes are also grease-lubricated—from below—special spring-operated "lifters" fitted in the keeps causing the grease to be applied under the axle journal; this is stated to give great economy in lubrication costs.

Another point of interest in the lubrication of American locomotives is the entire absence of independent suction lubricators, comparable to the "Furness" type, to come into action automatically when the engine is drifting. This is explained by the practice current there, of running down hill with the throttle slightly open, as mentioned elsewhere, thus keeping sufficient steam circulating to afford lubrication, together with the ordinary sight-feed lubricator. In some cases a special steam cock is provided in the cab for the express purpose of supplying this small amount of steam when drifting with an entirely

closed regulator. An excellent refinement on all modern American sight-feed lubricators is a master cut-out cock which controls all feeds (except that to the Westinghouse air pump when used) without interfering with the "setting." This avoids time and accuracy being sacrificed, and risk of inattention to signals, &c., with the driver occupied at each restarting of the engine.

The author's experience in the use of elastic packing *versus* the spring-supported lubricating pads of the British system, is that whilst the former needs more attention and hot boxes are rather more frequent than with the latter, yet the elastic packing is more economical. It must be remembered that although the first cost of either system is about the same, both the waste and the oil are reclaimed from the elastic packing, the waste used again in axle boxes and the oil for a lesser service. The author, lubricating on the American plan with oil obtains the following average consumption for heavy 108½-ton, twelve-wheeled engines with eight-wheeled tenders (= 20 axle boxes) working over the same severe curves and grades previously referred to, of: Engine oil, 30 miles per pint, and valve oil 68 miles per pint, which he believes will compare favourably with many British locomotives of much simpler design and on less difficult work.

Sand Boxes and Sanding Gear.—The primary difference between the British and American sanding systems is in the position of the sand boxes, which are placed on or under the running plate, or on top of the boiler barrel respectively. The other difference consists in the respective use of steam and compressed-air sanding apparatus, hand gear being used in both countries.

The position of the sand-box on top of the boiler has always been explained to the author as being for the purpose of keeping the sand dry by utilising the heat of the boiler. Although the sand is certainly kept hot, yet he cannot altogether support this, as experience shows that the position is, under certain conditions, actually conducive to "sweating" and packing of the sand, unless special ventilation of the sand-box is provided. When hand-operated valves are provided they are located in the base of the sand-box, and in the majority of cases in modern practice the air-operated valves are also placed there; in some instances the outlet is doubly controlled by hand and air, and the pipes therefrom, only containing sand when the valves are opened, give little trouble although a certain amount of sweating takes place. With air-operated valves placed about the line of the running plate, as was frequently the case and still is occasionally, the shut position leaves the pipes from the sand-box to the valve permanently full of sand, and this is liable to cause stoppage through the sand packing and sweating in the pipe. No difficulty is, as a rule, experienced between the air valves and the discharge, even though there may be considerable lengths of horizontal piping of small diameter.

There is further the disadvantage that sand is often spilled (generally over the motion and axle boxes) when filling the sand-box on top of the boiler at out stations and at night, &c.; if an obstruction chokes any of the outlets it is much easier for the fireman to go along the footplate and remove the obstruction by hand from inside the box, when placed as in British practice, than it is to go on top of the boiler. The large quantity of sand carried in the one box on the boiler, and the fact that it becomes fairly hot, makes it practically impossible for a man's arm to get down to the valve entrances.

For the foregoing reasons the author favours sand boxes being placed as in British practice, with the sand valves attached immediately under them; regarding steam *versus* compressed-air apparatus he can only say the steam system has the advantage of cleaning the rails, whilst with the air system much greater length and liberty in running level with small piping is obtained.

Brake Gear.—It is not proposed to go into the question of air brakes *versus* vacuum brakes, this being a subject of sufficient magnitude to form a paper by itself. Certain points in connection with brake rigging—foundation brake gear as it is termed in America—may, however, be noticed. The methods of attaching brake hangers to frames did not generally receive such care in American practice as in British, but nowadays more attention is given to the matter, and it has become general to provide special bosses and lugs integral with the bar framing for the purpose.

Another point of difference is that all, or almost all, modern American locomotives have the brake blocks applied at the back of the wheels instead of the position usual on British engines; there is, of course, a reason for this, as it is found that the brake action with the blocks in front added the pull on the blocks to the normal weight on the engine springs—made worse, the lower the blocks were applied—and affected them unfavourably. Subsequent developments indicate that the most convenient position for the brake cylinders is between the frames under the front ring of the boiler. By placing them there at about the height of the top rail of the frame and applying pressure towards the rear on long levers fixed to a shaft, attached to the lower rail of the frame, which has the necessary short levers extending downwards to couple with the brake pull-rods, a most straightforward arrangement is obtained. A further reason against placing the brake cylinders (when operated by compressed air, as in American practice) at the rear of the engine is that the heat from the fire-box and ash pan quickly perishes the piston leathers.

A good deal of trouble and expense is gone to, in order to make the brake gear equalised to allow for variations in the rods and wear of blocks, &c. This appears rather unnecessary, as if ordinary gear is properly adjusted when in the shops any subsequent variation, owing to some brake blocks being softer than others, is kept under control by the non-compensated gear and all the blocks caused to wear at approximately the same rate.

There is, of course, no question but that a form of "clasp" brake is always most desirable, to prevent any tendency to displace axles, and the author considers the British pattern as applied to the coupled wheels of many North Eastern Railway 4-4-0 type and to the Midland Railway compounds, in which a small floating cylinder and piston is used—due, he believes, to the late Mr. W. M. Smith—the most satisfactory yet devised; it is, unfortunately, not easily adapted to locomotives with four or five coupled axles owing to considerations of space.

Couplings and Draw Gear.—It is unquestionable that central automatic couplers as used in America are superior to the old British system of hooks, links and draw-bars, together with side buffers. Side buffers increase the resistance of trains rounding sharp curves—unless the couplings are slack, which is a defect in itself—and are theoretically incorrect. Further, the hooks and links are not sufficiently strong to cope with the large loads which are hauled in America, and in some of the Colonies.

The automatic coupler has the disadvantage for passenger work, that no matter how well it is maintained, there is always a certain amount of play in the interlocking together of the coupler knuckles, and it is possible in the case of a long train stopped rather quickly and couplers crowded in, for a driver to produce an appreciable jerk when starting the train; in this respect it is inferior to the British method when screw couplings are used, as on passenger stock.

Engine—Tender Couplings.—The usual methods of coupling engines and tenders together as practised in America are much less effective than the British methods; in many cases no spring device is fitted, the slack being taken up by a system of wedge and shoe. As provision for curving has to be made, it follows that there must be an allowance of slack when on the straight, and this leads to considerable jerking and strain on the draw-bar anchorages. Recently devices have appeared in which a spring is incorporated, although, as a rule, no provision is made for coupling under compression, and other designs providing for the angularity between engine and tender when on curves without allowing slack on the straight, have been brought forward.

Tenders.—The fundamental difference between British and American tenders is that the British pattern is constructed on the same principle as the locomotive with main frames, axle boxes working in horns, &c. The American tender is of a similar type of construction to a wagon, the frame consisting of four steel channels, and it has bogie trucks of the pattern used for wagons, having, as a rule, arch-bar side frames. These frames have axle boxes rigidly affixed thereto as on wagons, but the bogies otherwise differ in having better springing between the frames and truck bolsters. Several recent designs of bogies for very heavy tenders show a tendency to adopt independent or equalised springing for the axle boxes, together with considerable modifications to the arch-bar frame; in some cases a similar "bar and pedestal" frame to that employed for engine bogies is adopted. The channel-frame American tenders usually last about fifteen years, by which time the main channels and other parts require renewal, whereas the British tender, as is well known, last forty years or so and is often used on a second locomotive after its original partner has been scrapped.

Many varieties of tender tanks are employed in the United States, and have different advantages for special conditions, but the most common for many years has been the "U" shape pattern, although it is now being generally superseded by the water-bottom sloping-floor pattern. The "U" type compels the fireman to stoop to shovel from the bottom of the coal and, further, the coal space is not fundamentally self-trimming, although such effect is nowadays obtained by fitting direction plates.

The author considers the locomotive type of framing, the placing of the axle boxes in horns, and the water-bottom tank having the lowest part of the sloping coal space at a convenient height for the fireman, as in general British practice, much to be preferred to the American practice in these respects. It is remarkable that hardly any use is made of the water trough pick-up system as in England, as the water capacity and therefore weight of most of the tenders is very great.

Chilled Cast-Iron Wheels.—Although not now used on locomotives, but on wagons only, yet they are so characteristic of American railway practice that mention is made of them. They are, as would be expected, less reliable than any other form of wheel, but their simplicity and the combination of wheel and tyre, together with their cheapness, justify their use in many countries. They suffer particularly from flats on the tread caused by shelled spots or by skids, occasionally from cracks in the flanges, and less often from cracks in the bosses; these defects, however, are easily seen and the defective wheel replaced. Condemned wheels are—at any rate abroad—used in the locomotive foundry and are found to give excellent results. The author has cast cylinders, also locomotive spoked wheels, from such scrapped wheels, with the addition of only 15 per cent. of pig-iron, with success. It should be understood that he is not advocating the use of these wheels, considering that the various rolled and cast steel wheels are much better; but not having any direct comparisons to base an opinion on, he is naturally not prepared to say that a practice universal in America and particularly with the large capacity wagons with such wheels in use there, is incorrect.

Coal Consumption.—Unfortunately the author is not able to give a comprehensive table of comparisons owing to the extreme variations in the services worked; he has, however, had a table prepared which refers to five locomotives on identical services, namely, heavy fruit trains weighing 160 tons to 170 tons on the hill sections meeting about 37 per cent. of 1 in 30 up-hill gradient on the run.

The first section indicates a small difference in favour of the British locomotives (despite that their boilers were too small at that time), and this is supported by the second section; the aggregate increase in consumption is due to increased loads. It is to be noted that although by the second period the British engines had been rebuilt with 50 per cent. larger boilers, the increased consumption was less than that of the others; this result is similar to that found in the case of the Great

Jamaica Government Railways—Comparison of Coal Consumption.

Class.	Engine No.	Period.	Average Pounds per Engine Mile.
E British locomotive, built 1901	27–29	April, 1912–March, 1914	72
G American locomotive, built 1908	25, 26	April, 1912–March, 1914	76
E 1	28, 29	April, 1915–March, 1917	81
	27	April, 1919–March, 1921	
G	25, 26	April, 1917–March, 1919	91

Class E.—4-8-0 type; cylinders, 19½ in. × 24 in.; driving wheels, 3 ft. 10 in.; boiler pressure, 180 lb. per square inch; total heating surface, 1,412 sq. ft.; grate area, 24·25 sq. ft.; weight in working order (E and T), 93 tons 14 cwt.

Class E 1.—(Class E, rebuilt with enlarged boiler). Boiler pressure, 180 lb. per square inch; total heating surface, 2,122 sq. ft.; grate area, 30 sq. ft.; weight in working order (E and T), 100 tons 16 cwt.

Class G.—4-8-0 type; cylinders, 19 in. × 26 in.; driving wheels, 3 ft. 10 in.; boiler pressure (first period), 190 lb. per square inch; (second period), 180 lb. per square inch; total heating surface, 1,925 sq. ft.; grate area, 30 sq. ft.; weight in working order (E and T), 101 tons 6 cwt.

Northern Railway 4-4-2 type, in which the larger boilers were found the most economical. This is substantiated by the running results during the past year or so of two sets of locomotives under the author's observation, in which the set with larger boilers show less coal consumption per mile than those with smaller boilers, although the locomotives are otherwise similar and on similar services.

In conclusion the author believes it will appear clearly from the paper, and no doubt this will be supported by most locomotive engineers who have had control of British and American locomotives, that the locomotive has developed on the same basic principles both in England and the United States of America, the principal differences being due to the respective conditions and service requirements.

In regard to details, however, it is considered that there is scope for improvement, on the British side by adopting American practices suitable for service in partly-developed countries, and on the American side by the adoption of more substantial and wear-resisting details as developed in British practice.

On the most important point of divergence—the bar *versus* the plate frame—the author considers the bar frame *per se* undoubtedly most suitable for North American conditions of development; and that the plate frame is most suitable for conditions in Great Britain, and likely to remain so whilst the present loading gauge remains. For Colonial and foreign conditions he rather favours the bar frame, except for side tank engines in which the plate frame raised well above the axle boxes provides advantages for supporting the tanks not possessed by the bar frame, nor for its merits as a frame, but on account of certain facilities it provides for other details; the point is a very fine one, providing, as already mentioned, the horns of plate-framed engines are of specially substantial design for such service.

POSITIVE-RAY ANALYSIS OF LITHIUM AND MAGNESIUM.—The method of positive-ray analysis of A. J. Dempster, of the Ryerson Physical Laboratory, differs from the classical methods of J. J. Thomson and Aston. The positively-charged atoms are allowed to fall through a definite potential difference; a narrow bundle of the rays is separated out and bent into a semicircle by a strong magnetic field; by varying the field or the potential the rays are made to fall on a second slit and to give up their charge to an electroscope; the molecular weight of the particles can then be calculated. In a modified method the magnetic field is kept constant, and the ratio of the potentials is determined for which the rays have the same radius of curvature; this potential is inversely proportional to the atomic weight. In the apparatus used the source of the rays is a small cylindrical anode containing the metal to be studied or its salt, which is heated by a concentric coil and bombarded by the electrons. Lithium was found to have an isotope; the accepted atomic weight of lithium is 7, and Dempster (*Physical Review*, December, 1921) found values 7·02 and 5·98; the relative proportions of these isotopes varied with the experimental conditions. In the case of magnesium, with an accepted weight of 24, three isotopes of atomic weights 24, 25, 26, were found, and their relative proportions were as 7 : 1 : 1; but these proportions were not very constant and reliable. That may be due to different rates of evaporation of the isotopes.